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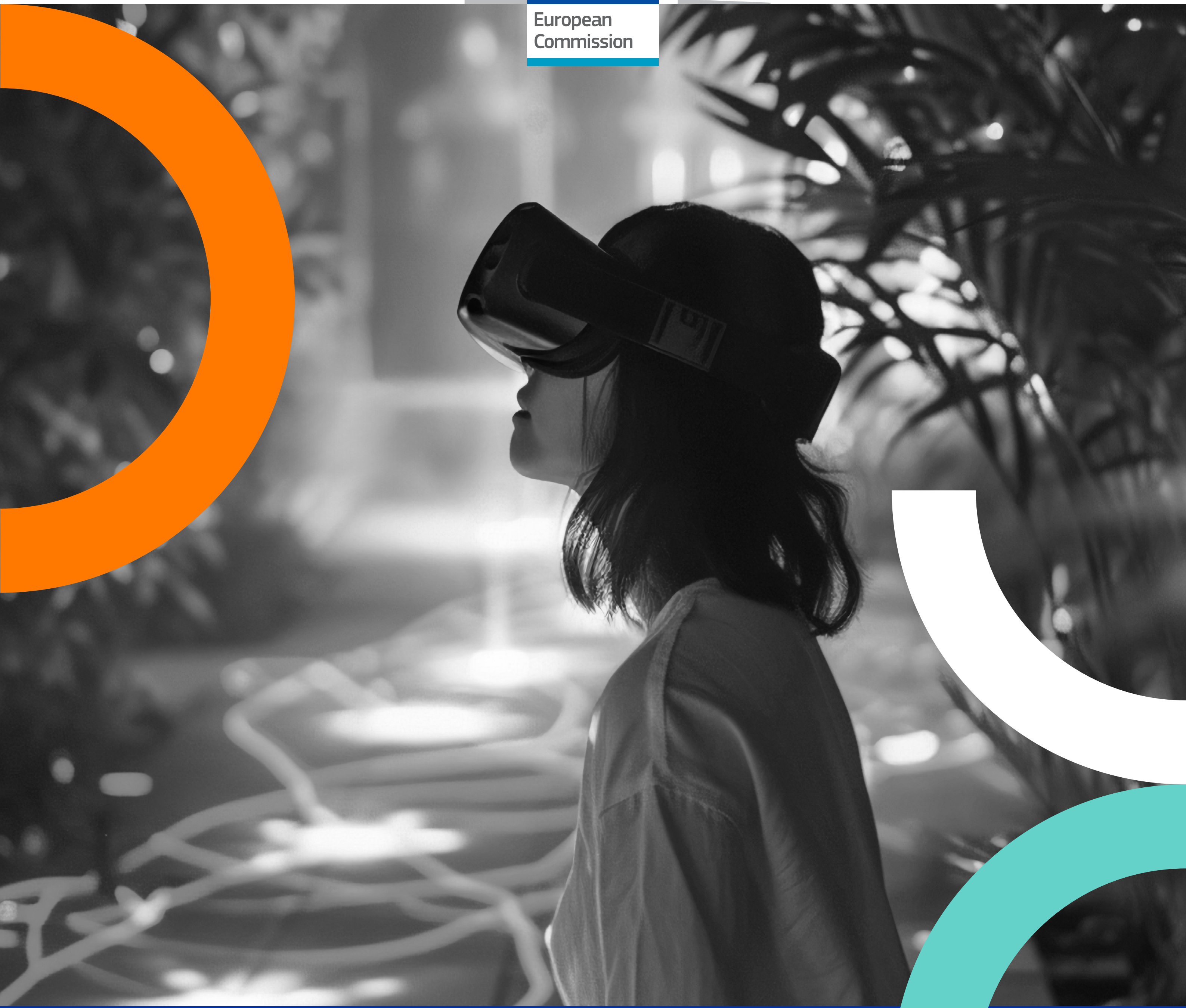

A guide for educators

Immersive learning: innovative pedagogies, techniques, best practices and future trends

by the European Digital Education Hub's squad on immersive learning

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The European Digital Education Hub (EDEH) is an online community for practitioners from all sectors of education and training aiming to contribute to improving digital education in Europe. To achieve this goal, EDEH is not only a place for exchange and discussions but also offers a variety of different events and activities. These activities include the squads that are online working groups where community members can collaborate on a specific topic of digital education. This document is the result of the work of the EDEH squad on immersive learning.

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Introduction

Jackie Toal

Introduction

Background

The topic of immersive learning is not only interesting in its own right, but also a "hot topic" when looking at the world around us. At the time of writing – spring/summer 2024 – there are numerous discussions going on about the use of virtual reality (VR), augmented reality (AR) and mixed reality. In order to be up to date on the latest developments, it is important that educators and learners are aware of how immersive learning can be used. The topic relates to the European Digital Education Plan (2021-2027), especially Priority 2 (enhancing digital skills and competences for the digital transformation), and also with the United Nations Sustainable Development Goal of ensuring "inclusive and equitable quality education".

The aim of this document is to share insights, inspire and offer guidance to educators in the realm of immersive learning by providing tools, techniques and approaches so that they may be equipped with the underpinning knowledge of how to implement into their own practice. Core pedagogical and design considerations are explored, examples of best practice in the context of a European related area are shared. Some insights into future trends and recommendations are also investigated in this document.

Immersive learning

Immersive learning offers the promise of engaging learners, cognitively, emotionally and physically in their learning experiences. It can have positive impact on emotions compared to traditional desktop-based learning (Lønne et al. 2023).

Immersive learning is defined as learning associated with 'real-to-virtual experiences' (Aguayo & Eames 2023, p. 58). It encompasses the use of technologies such as VR, AR and mixed reality. Immersive learning allows students to become active participants in the construction of their own knowledge. Additionally, it is a form of learning that encompasses a range of multi-sensory stimuli to enhance engagement and encourage critical thinking and problem solving through hands-on experiences (Almulla 2023). Immersive learning intersects with various types of knowledge building, including experiential learning, adaptive personalised learning, multi-modal sensory experiences and immersive storytelling. The development of metaverse technologies and web 3.0 technologies (Nisiotis & Alboul 2021) offer new and exciting digital education pathways for immersive learning.

Immersive technologies

Immersive technology, or extended reality (XR), is an umbrella term to encapsulate the above-mentioned VR, AR and mixed reality.

Of these, VR, where users wear headsets to become immersed in a virtual world of computer 3D graphics, is considered the most immersive. In some research, there is a distinction made between "low immersive VR" and "high immersive VR" (Makransky and Petersen 2021; Radianti et al. 2020). This creates the feeling of being there, which can enhance engagement and presence (Ahn and Noh 2024). Hurrell and Baker (2020, p. 197) state that VR encompasses most of the senses, 'representing an alternative reality'.

Mixed reality combines both physical and digital environments to allow users to interact simultaneously with both the real and the virtual. A virtual object could be a holographic avatar or object. The use of specialised headsets or glasses facilitate this. Song et al. (2023) highlight that mixed reality can provide diverse opportunities for practice as well as inclusive education (Mateu et al. 2014).

AR involves a user who is in the real world but with an overlay of virtual assets. This is the least immersive form and, in many instances, involves the use of a smartphone. It can enhance learning experiences via interactive visualisations, simulations and content as an overlay to enhance education and learning (Interaction Design Foundation 2016).

Aims

The aim of this guide is to introduce educators to the key concepts of immersive learning - what it entails and its interrelated sectors - and serve as a knowledge base for those who may be interested in applying immersive learning pedagogy to their vocational fields and practice.

The target audience includes educators, such as teachers in secondary education, and lecturers in post-vocational, further education, and higher education sectors.

Objectives

To facilitate this overarching aim, the following objectives are outlined:

1. To provide knowledge of innovative techniques and pedagogical approaches to support and inspire educators.
2. To share examples of best practices to guide educators on how to implement immersive learning into their own teaching practices within their educational establishments and inspire learning.
3. To share knowledge on opportunities, limitations, recommendations, tips and suggestions for embedding immersive learning into curricula.

These core objectives are explained in each of the subsequent sections in detail, including techniques and pedagogy, best practices, and future trends and recommendations.

In the techniques and pedagogy section a diverse range of strategies are explained with detail on both pedagogical and design approaches, suggested tools and software, benefits of these as well as how they may align to the European Digital Education Action Plan.

In the best practice section, there are real- world case studies to inspire educators with details on their purpose, goals, and learning objectives as well as how these have been disseminated within the wider educational community.

The section on future trends and recommendations addresses emerging examples of technologies, challenges, and forward-looking suggestions for the use of immersive learning technologies to support and inspire educators.

References

Aguayo, C., Eames, C. (2023): Using mixed reality (XR) immersive learning to enhance environmental education, The Journal of Environmental Education, 54(1), 58–71, https://doi.org/10.1080/00958964.2022.2152410.

Almulla, M. A. (2023): Constructivism learning theory: A paradigm for students' critical thinking, creativity, and problem solving to affect academic performance in higher education, Cogent Education, 10(1), https://doi.org/10.1080/2331186x.2023.2172929.

Ahn, J., Noh, G.Y. (2024): Optimizing the Educational Potential of Virtual Reality: The Effects of Virtual Reality and Pop Quizzes on Spatial Presence and Efficacy Perceptions, International Journal of Human-Computer Interaction, 1–12, https://doi.org/10.1080/10447318.2024.2313274.

European Commission (2021): Digital Education Action Plan (2021-2027), European Education Area, https://education.ec.europa.eu/focus-topics/digital-education/action-plan (accessed 2 May 2024).

Hurrell, C., Baker, J. (2020): Immersive learning: Applications of virtual reality for undergraduate education, College & Undergraduate Libraries, 1–13, https://doi.org/10.1080/10691316.2020.1796879.

Interaction Design Foundation (2016): What is Augmented Reality (AR)?, Interaction Design Foundation – IxDF, https://www.interaction-design.org/literature/topics/augmented-reality (accessed 2 May 2024).

Lønne, T. F., Karlsen, H. R., Langvik, E., Saksvik-Lehouillier, I. (2023): The effect of immersion on sense of presence and affect when experiencing an educational scenario in virtual reality: A randomized controlled study, Heliyon, 9(6), e17196, https://doi.org/10.1016/j.heliyon.2023.e17196.

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.

Mateu, J., Lasala, M. J., Alamán, X. (2014): VirtualTouch: A Tool for Developing Mixed Reality Educational Applications and an Example of Use for Inclusive Education, International Journal of Human-Computer Interaction, 30(10), 815–828, https://doi.org/10.1080/10447318.2014.927278.

Nisiotis, L., Alboul, L. (2021) : Work-In-Progress-An Intelligent Immersive Learning System Using AI, XR and Robots, 7th International Conference of the Immersive Learning Research Network (ILRN), https://doi.org/10.23919/ilrn52045.2021.9459358.

Song, B., Lim, M., Lim, K. (2023): Stories of Online Art Education: Transitions and Challenges During the Pandemic, Art Education, 76(4), 40–48, https://doi.org/10.1080/00043125.2023.2211216.

United Nations (2023): Goal 4, Ensure Inclusive and Equitable Quality Education and Promote Lifelong Learning Opportunities for All, United Nations, https://sdgs.un.org/goals/goal4 (accessed 2 May 2024).

PART 1

Techniques and pedagogical approaches

1. Techniques and pedagogical approaches

Jackie Toal

With the rapid development in digital education, immersive technologies open opportunities for innovative pedagogy (Matovu et al. 2023). To explore the opportunities that digital education creates for immersive learning, we will first review the pedagogical approaches that have been used to underpin immersive learning experiences before considering some design factors that may be used to inform their development. Pedagogy is the approach and practice of teaching. This is important as the use of immersive technologies in learning promotes critical thinking, social collaboration, assessment, problem-solving, enhanced engagement, and aids in the construction of knowledge and development of higher-order skills. This in turn will help ensure achievement of educational goals.

It encompasses the core techniques, processes, strategies, and underpinning theory to help support learning. It also involves understanding how students learn to meet their needs. Many factors need to be considered in the process, including curriculum, environment, assessment, teaching strategies and students. In the following sections both pedagogical approaches and design considerations are explored with examples. These pedagogical approaches and design considerations for immersive learning are drawn from the perspective of experienced professionals in the field of education.

1.1. Experiential learning approaches

Cristina Obae

'A common usage of the term "experiential learning" defines it as a particular form of learning from life experience; often contrasted with lecture and classroom learning' (Kolb 1984). It is an in-context experience where the learner is confronted with real-life situations going through the stages of experiencing, reflecting, thinking, and acting as illustrated below:

Figure 1: Kolb's learning cycle.
Source: Institute for Experiential Learning n.d.

Using the notion of experiential learning in designing VR courses, we can allow students to engage their senses and create a sense of presence or immersion.

VR allows real-life simulations and construction of scenarios that put the student in such experiential situations. The technology provides opportunities for customising the experiences, altering the scene, time, place, and people learners encounter, offering an enhanced yet controlled reality where social interaction and discovery are possible.

1.2. Immersive storytelling

Anhelina Bykova

Immersive storytelling can be defined as a technique that uses digital technologies to provide the audience with interactive and immersive experiences. Such a technique allows the users to play an active part rather than just being a passive observer. It is therefore a very interesting and useful technique for the educational process (Chopra et al. 2021). Immersive storytelling creates a sense of reality within the audience, providing a different perspective and this way facilitating the perception of different concepts (Gröppel-Wegener and Kidd 2019). Some of the forms immersive storytelling can take are real-world and real-time events, prerecorded videos, live-feed videos, animation, games, audio and commercials.audio and commercials.

An interesting example of immersive storytelling is Clouds Over Sidra – a VR video created by Gabo Arora and Chris Milk and co-produced by VRSE and the United Nations. Other interesting and highly involving immersive storytelling videos were created by National Geographic among others.

1.3. Inquiry-based learning in VR

Ivan Moser

Inquiry-based learning (IBL) is a pedagogical approach where the teacher assumes the role of a facilitator rather than a lecturer presenting their subject knowledge (Turan 2021). In this regard, IBL is closely related to other learner-centred concepts, such as experiential learning. A teacher that employs IBL in their teaching helps their students apply methods and practices comparable to those of scientists. This includes the formulation of research questions and the testing of hypotheses via observation or experiments (Lippmann 2021). The teacher-as-facilitator introduces the topic and stimulates the students' curiosity in an orienting phase, and then provides adequate guidance across the different phases of scientific inquiry.

Several meta-analyses comparing IBL with lecture-based direct instruction support the effectiveness of including inquiry practices in teaching. For example, in their detailed analysis of 37 studies, Furtak et al. (2012) found an overall positive effect of inquiry practices on learning outcome, while pointing out the importance of adequate teacher guidance.

In this light, it is not surprising that an increased emphasis is being placed by both educators and policymakers to promote effective learning using inquiry-based teaching strategies (Ramnarain and Schuster 2014). However, the promises of IBL are often not realised due to a lack of adequate knowledge and experience to enact inquiry practices (Asay and Orgill 2010).

Due to the high level of immersion, social and object interactivity, VR and related technologies represent the perfect candidates to realise and support inquiry practices in the (virtual) classroom and high levels of acceptance among pre-service teachers have recently been reported (Ogegbo et al. 2024).

Since VR learning experiences have been shown to promote motivation and learning satisfaction (Di Natale et al. 2020), the technology can support the orienting phase of IBL. Moreover, educators can leverage an array of tools present in existing VR applications (e.g. FrameVR or Microsoft Mesh, including slide presentations, whiteboards, and the option to import 360-degree-videos or interactive 3D objects, all of which can be used to support inquiry practices such as active experimentation. It is noteworthy, however, that customised object interactivity can be hard to achieve without the use of and expertise in game engines such as Unity. Fortunately, the emergence of no-code prototyping tools (for example ShapesXR) allows educators to convey their ideas to collaborating technical personnel, increasing efficiency and reducing development cost.

Figure 2: Example of a virtual classroom developed in the Unity Game Engine.
Source: Moser et al. 2024.

Figure 2 is an example of a virtual classroom developed in the Unity Game Engine. It is used with pre-service teachers to practice their IBL teaching skills (Moser et al. 2024; Penn et al. 2024).

Alignment with the Digital Education Action Plan

The pedagogical approach of fostering inquiry practices using VR aligns with the Digital Education Action Plan, by supporting 'the creation and application of digital pedagogies and of expertise in the use of digital tools for teachers' (Action 5).

1.4. Virtual immersive environments for collaborative learning

Irina Otmanine

The design of collaborative virtual environments for learning is deeply rooted in the idea of learning as a social process.

As research says, one of the main problems of online learning is isolation for the student, resulting in decreased performance. By considering learning as a social process, where individuals create meaning through interactions with others and the environment rather than an individual experience, this risk might be minimised. Similarly, the sociocultural theory of learning (Vygotsky 1978) states that learning takes place when it is social, active, and situated.

So how do these theories support the appearance and development of virtual immersive environments? In online learning environments, we often speak about "social presence" (Barreda-Ángeles and Hartmann 2022). Social presence theory argues that media differ in the ability to convey the psychological perception that other people are physically present due to their different abilities to transmit visual and verbal cues (Paoli and Otmanine 2022).

In that sense, the development of highly immersive environments can help increase social presence in the context of online learning and support learners to become more involved from a cognitive and emotional point of view.

However, the fact that an immersive environment is open to an online community is insufficient to ensure that its functions are explored and used by potential learners. To make collaborative learning happen in an immersive environment, it is important to consider the following:

An appropriate learning scenario is crucial to defining and setting collaborative learning activities. Some examples include problem- and project-based learning activities in small groups, treasure hunts, and virtual learning expeditions (Radianti et al. 2020).

Figure 3: Example of a treasure hunt in an accounting course in Virbela collaborative learning environment. Source: Virbela. By Irina Otmanine - SKEMA Business School.

Even with ongoing progress in VR technology, there are still potential restrictions related to graphic quality, computational capacity, and network connections that could greatly influence the practicality and effectiveness of collaboration within VR spaces (Doroudian 2023). Such challenges are particularly pronounced in contexts with inadequate network infrastructure or where user bandwidth is constrained. It can be useful to check these parameters before starting the course and suggest technical solutions to learners.

An onboarding session can be organised before starting the course so that learners are familiar with the environment, essential functions, and structure of the virtual space. Some basic activities can be proposed during this session (collaborative document sharing, pooling, and following a specific path in a virtual space). Some more detailed general recommendations regarding design for collaborative learning in virtual environments can be found below.

General design recommendations for collaborative learning in immersive virtual environments (adapted from Paulsen et al. 2024).

Table 1: General design recommendations.

Category	Description	Examples of practices
Pedagogy and technical usability	Pedagogy and technical usability should be viewed as entangled, designing for both social knowledge construction as well as user friendly experiences with a focus on collaborative learning.	Align the technical features with pedagogical goals. Include relevant stakeholders in the design and evaluation of immersive environments and activities.
Learning goals and activities	Activities should be centred around a shared goal or problem that must be attended to collaboratively and aimed at developing and practicing skills and competencies.	Define clear learning objectives that support a collaborative learning process. Ensure that learning objectives, immersive environments, and activities are in alignment with each other and pedagogical concepts and goals.
Participation and social interaction	Immersive environments for collaborative learningshould be designed for participation and social interaction.	Include mediating avatars that are recognisable or customisable while striving to mediate as much bodily conduct as possible – e.g., through different coloured avatars or lip-synced avatars. Create methods for establishing spatial awareness, joint attention and perspective-taking, such as bodily orientation, and tools for marking objects as relevant – e.g., through laser pointers.
Immersive environments and degrees of realism	An active choice should be made regarding the degree of realism when designing the immersive environment for collaborative learning, whether programmed or 360-degree-videos based.	In programmed environments, emphasis should be placed on creating presence through designing interactions that emulate the real world. In 360VR environments, the emphasis should be on creating presence by being immersed in an authentic re-mediation of practice – e.g., through videos of non-scripted interactions In both types, design should not only focus on affording interaction with the environment, but also interaction with other users, creating co-presence.
Teaching presence and support	Activities should be supported by human or digital scaffolds.	Guide learners in supporting their collaborative learning processes. Support learners in reflecting – e.g., through video prompts. Give learners feedback on their actions.
VR and real-world activities	Knowledge constructed in VR should be made transferable or actionable outside of VR.	Use VR as a tool to pre-qualify face-to-face learning/training. Facilitate debriefing or group discussion in order to reflect on the experience. Support reification, allowing participants to take the constructed knowledge with them across realities.

Some examples of tools to set up an immersive collaborative environment and their main features can be found below.

ENGAGE is a platform that 'provides a variety of tools for collaboration, such as immersive white boards, screen streaming, 3D virtual pens, and spatial [Voice-over-IP] communications, to enable more natural meetings and classes at a distance'. The solution offers possibilities to '[b]uild digital twins of real locations and use them in fully secure networked environments for education, collaboration, and simulation training' (Engage 2024).

According to the information provided by the company on the website, ENGAGE supports PC, Mac, iOS, Android and almost all spatial computing devices on the market today. It also claims to be General Data Protection Regulation (GDPR)-compliant.

The recent integration of OpenAI and multiple generative AI tools is an interesting feature, as it enables users to interact with AI-controlled avatars and generate in-world assets.

Virbela is a low-immersive VR software compatible with almost any PC or Mac computer. It does not require the use of a VR headset but involves downloading the client directly to the computer. Users can then personalise their avatars and enter the space called Virbela Open Campus to start exploring spaces, communicating with other users, or creating their own environment for learning and collaboration (Virbela 2024).

The software offers the possibility to design a virtual classroom, a space for a virtual event or exhibition, or a whole virtual campus for different group sizes. It offers collaborative tools such as breakout rooms, screen sharing, sticky notes, video sharing, and others.

Virbela claims to be GDPR-compliant and offers an Enterprise security package.

FRAME is a solution from Virbela that offers communication, collaboration, and creation features in 3D environments, right from the web browser (no need to download a client). It can be used for immersive team meetings, engaging online education environments, spatial online events, as well as digital twins of real-world locations.

Among its features: imports of content (3D models, 360-degree-photos, webcam, screen-share) accessible on desktop, mobile, and VR headsets, white-labelling and a custom URL, supporting 1,000 users per space. According to the provider, FRAME can be hosted on GDPR-compliant servers.

Microsoft Mesh is a platform developed by Microsoft that enables shared immersive experiences. Virtual collaboration spaces can be started from either the dedicated Mesh desktop application or directly from a running Microsoft Teams meeting. Users can choose from several pre-configured virtual spaces or create their own customised 3D environments with a no-code editor and toolkit. The meetings can also be joined via the Meta Quest headsets. Being integrated into the widespread Microsoft 365 product family, Mesh claims to be fully GDPR-compliant.

1.5. The use of gamification in immersive learning environments

Ayşegül Liman Kaban

Gamification is the integration of game elements and mechanics into non-game contexts to enhance engagement, motivation, and learning. In immersive learning environments, gamification can be a powerful tool to make educational experiences more enjoyable, interactive, and effective. Gamification significantly impacts student engagement and motivation in immersive learning environments (Alsadoon 2023; Felkey et al. 2023; Huseinović 2023; Luarn et al. 2023). Elements like collaboration, competition, feedback, self-expression, and control play crucial roles in enhancing intrinsic motivation. Studies in various fields, including computer essentials, English language learning, and technology-based tasks, consistently show positive outcomes on motivation and engagement levels.

Gamification strategies not only improve motivation but also lead to increased academic performance, skill development, and overall success in learning. The integration of gamification in education is recommended to leverage the benefits of enhanced motivation, engagement, and learning outcomes, emphasising the importance of aligning gamification design with educational theories for optimal results.

Here are some examples of how gamification is used in immersive learning:

Language learning apps: Many language learning apps, such as Duolingo and Rosetta Stone, incorporate gamification elements to motivate learners. They use features like points, levels, and badges to track progress and reward achievement. Learners earn points for completing lessons, practicing regularly, and achieving mastery in various language skills. By turning language learning into a game-like experience, these apps encourage users to stay engaged and motivated to continue learning.

STEM education platforms: Gamification is commonly used in STEM (science, technology, engineering, and mathematics) education to make complex concepts more accessible and enjoyable for students. For example, platforms like Minecraft Education Edition and Code Combat gamify coding and computer science education by allowing students to solve coding challenges, build projects, and collaborate with classmates in a virtual environment. By turning programming into a game, these platforms make it easier for students to grasp abstract concepts and develop problem-solving skills.

Health and wellness apps: Gamification is also used in health and wellness apps to encourage users to adopt healthy behaviours and lifestyle habits. For instance, fitness apps like Fitbit and Strava use gamification elements such as step challenges, virtual rewards, and social competitions to motivate users to exercise regularly and reach their fitness goals. By turning physical activity into a game, these apps make exercise more engaging and enjoyable, leading to increased adherence and better health outcomes.

Corporate training programmes: Gamification is increasingly being used in corporate training programmes to enhance employee engagement and retention of key concepts. For example, companies may use gamified e-learning platforms to deliver compliance training, sales training, or onboarding programs. These platforms incorporate game elements such as quizzes, simulations, and leaderboards to make training more interactive and competitive. By gamifying the learning experience, companies can improve knowledge retention and skill development among employees.

Environmental education initiatives: Gamification can also be used to raise awareness and educate people about environmental issues. For example, apps like Eco provide virtual simulations where players can learn about ecosystem dynamics, conservation strategies, and the impact of human activities on the environment. By completing challenges, players can earn rewards and contribute to virtual reforestation efforts. These gamified experiences not only educate players about environmental issues but also inspire them to take real-world action to protect the planet.

In summary, gamification enhances immersive learning environments by leveraging game elements to increase engagement, motivation, and learning outcomes across various educational contexts, from language learning and STEM education to health and wellness and corporate training.

1.6. Learning in immersive environments

Cristina Obae

Tool: **ENGAGE**

Objective: learning the pronunciation rules for the French digrammes and trigrammes

Audience: high school students, beginner (A1) French language learners

Duration: 60 minutes

The learning goals of this experience are to acquire new information concerning the French digrammes and trigrams illustrated in figure 4. Invited into a 3D personalised tropical island, students are immersed in a scenario-based project. The instructions are presented as a problem learners need to solve: Animals escaped from a shipwreck and got to the island. In order for the rescuers to be able to catch them, they need to write each animal's name in French on a post-it, then organise them in categories depending on the groups of letters pronounced as one sound that are to be found in their French name. Each group of animals will go into a specific cage. You need to figure out which cage to put each animal in and stick the post-it to that cage.

Figure 4: VR learning environment for learning French pronunciation rules.
Source: ENGAGE.

All the stages of Kolb's experiential learning cycle illustrated in figure 1 are present in the learning experience, and ENGAGE affordances support the process: Students experiment through exploring the island, discovering different animals, using an online dictionary for finding their names' pronunciation, reflecting through reading out loud, thinking and working together to discover the commonalities and negotiating the division into categories, then finally acting by writing the names of the animals on post-its and sticking them on the cages. Going through all these steps, they manage to uncover, without even realising it, the essential pronunciation rules of the French language.

1.7. VR and augmented virtuality: design of digital twins as a technique to teach practical work in chemistry

Thierry Koscielniak

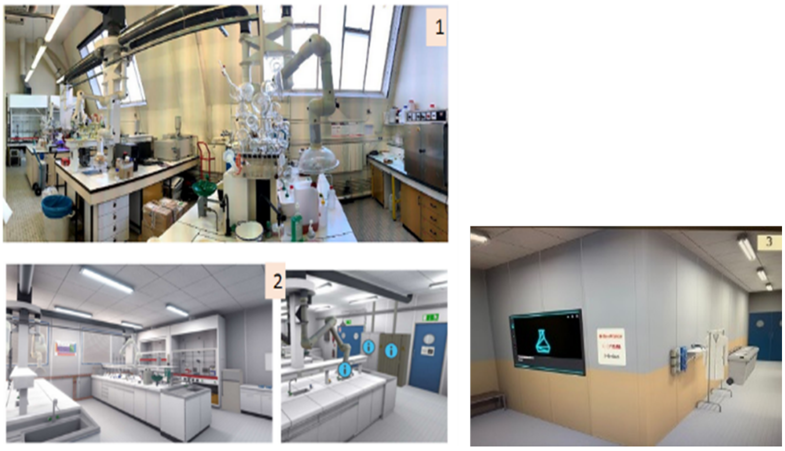

Figure 5: Immersive chemistry lab. 1) Real chemistry laboratory located at 2 rue Conté, Paris 75003. 2) Immersive digital twin laboratory in VR. 3) Reception and security area for the immersive digital twin laboratory in VR. Source: 1) Picture taken by Thierry Koscielniak in Cnam Laboratory 2) and 3) Screenshots from MIMBUS Company.

The virtual laboratory, or digital twin, replicates a chemical laboratory space equipped with fume hoods, dry benches, and various equipment and reagents necessary for chemical experiments. It was designed to offer an immersive learning experience in VR, allowing students to familiarise themselves with the equipment, and safety procedures and practice specific laboratory techniques without the risks associated with handling real chemical substances.

General learning objectives

The learner will be able to: (1) move safely in a chemistry laboratory, (2) identify laboratory equipment and associated uses, (3) acquire the correct techniques in terms of laboratory procedures, and (4) use laboratory equipment and apparatus appropriately in the context of a given practical experiment.

A: Example of practical work using VR

Step 1: Via the interface of the learning management system Moodle, the students receive the preparatory documents for the practical work:

- A practical booklet describing the experiments that will be carried out in the laboratory.
- A document containing the safety concepts to be understood before the practical session.
- A specification document containing all the elements needed to understand the immersive session (use of a VR headset, use of joysticks, colour codes, etc.).

Step 2: Preparation of a room equipped with four workstations (VR helmet and computer), a Wi-Fi router, and a cleanbox for disinfecting and drying the VR helmets.

Step 3: Equipping learners with VR headsets and controllers. Immersion exercises using joysticks to interact with the environment: moving, operating, grasping, opening, etc. (5-10 minutes, depending on the learner).

Step 4: The learners are now equipped with a VR headset and joysticks. They enter the immersive session and put on their personal protective equipment (PPE, gloves, goggles and smock). Throughout the exercise, the learners will be accompanied by a tablet that can be consulted on the left wrist to guide them through the various functions.

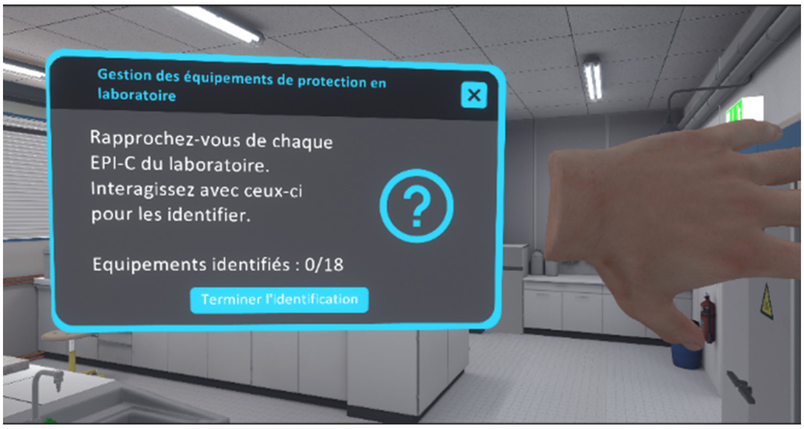

Figure 6: Interactive tablet to guide learners during immersive sessions.
Source: Screenshot from MIMBUS SAS company.

Step 5: Identifying collective protective equipment (CPE). By clicking on them with the handle, the learner first identifies the collective protective equipment in the chemistry laboratory. The objectives and aims differ according to the level of difficulty chosen.

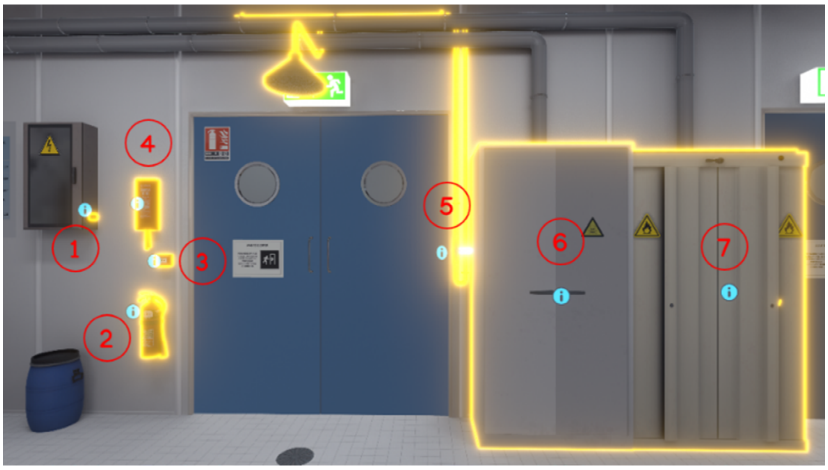

Figure 7: CPE 1 to 7 to identify parts in a laboratory.
Source: Screenshot from MIMBUS SAS company.

Step 6: Managing risks and hazards in the laboratory: Projection. The learner must then carry out a liquid/liquid extraction when they accidentally spill chemicals into the fume cupboard and onto themself. They must react accordingly to eliminate the hazard safely. Depending on the chosen level of difficulty, the objectives and guidance for the actions to be performed will differ.

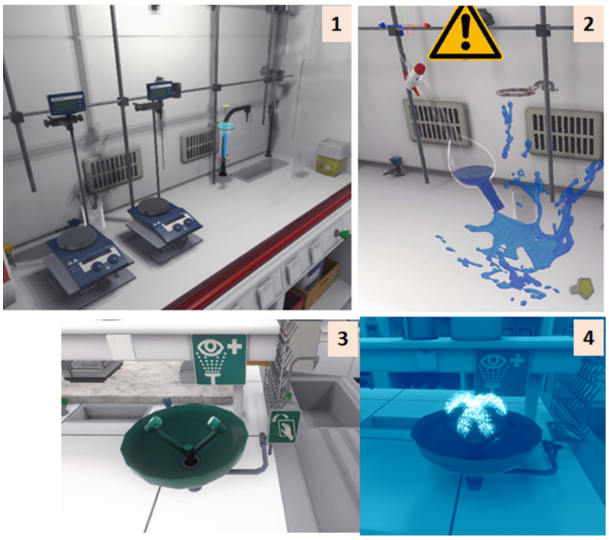

Figure 8: Steps in an educational scenario for managing the projection hazard. 1) Workstation for carrying out the liquid-liquid extraction. 2) The separating funnel falls, and the liquid is projected around it. 3) Eyewash available in the laboratory. 4) Eyewash triggered - the blue filter indicates to the learner that a chemical product has been projected into his eyes.
Source: Four screenshots from MIMBUS SAS company.

Step 7: Routine laboratory operations: reflux set-up.

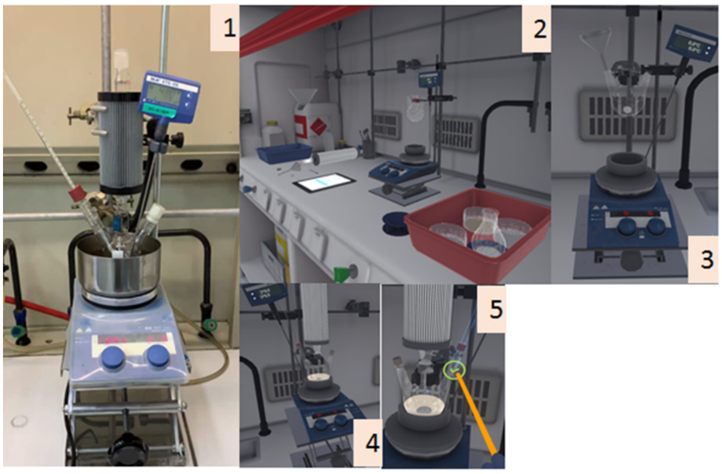

Figure 9: Stages in a teaching scenario for setting up a reflux set-up. 1) Actual workstation for a reflux set-up in the laboratory. 2) Equipment available on the fume cupboard in the laboratory. 3) Installation of the reactor (tricol) before the reagents are transferred. 4) Installation before setting temperature and stirring parameters. 5) Confirming the temperature with the thermometer.
Source: 1) Picture taken by Thierry Koscielniak in Cnam Laboratory 2), 3), 4), 5) Four screenshots from MIMBUS SAS company.

During this session, the learner will mix and heat different products in a reactor (tricol) to merge them using a reflux set-up with a magnetic stirrer. Depending on the chosen level of difficulty, the objectives and guidance for the actions to be carried out will differ.

Step 8: Once the exercise has been completed, the learner is taken back to the reception area and presented with a score screen showing the results of the exercise like in figure 10. The score screen shows whether the exercise has been validated. The results for each targeted learning objective are displayed as a percentage of success, along with the exercise assessment criteria and the events indicating all the actions validated by the user from the start of the exercise.

Figure 10: Score screen.
Source: Screenshot from MIMBUS SAS company.

Step 9: After 35 minutes of immersive experience in the VR the teacher immediately asks for feedback on how the practical session went. This stage is vital for anchoring knowledge.

Step 10: The teacher assesses the success and skills acquired by the learners via an analytics platform, which facilitates pedagogical monitoring through the provision of a dashboard displaying learning traces. On this basis, the teacher can then create personalised remedial pathways for their learners.

VULCAN is a free learning analytics platform for VR teaching modules provided by the MIMBUS company and is interoperable with all learning management systems (figure 11).

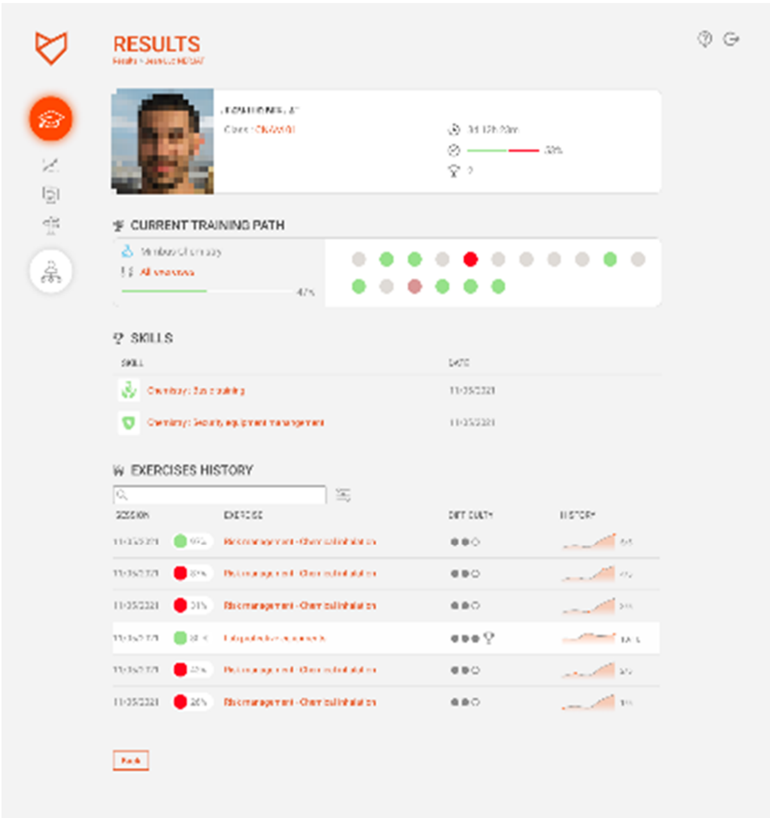

Figure 11: Example of visual feedback from the VULCAN Analytics platform.
Source: Screenshot from MIMBUS SAS company.

B: Example of practical work using augmented virtuality

An augmented virtuality system with a green background has been tested with class groups of around fifteen learners in the presence of their teacher. One member of the class is fitted with a VR headset and immersed in the digital twin. His or her image, filmed against a green background, is embedded in the 3D environment in real time.

Figure 12: Use of the augmented virtuality facility with a green background (1).
Source: Picture taken by Thierry Koscielniak in France Immersive Learning's Lab.

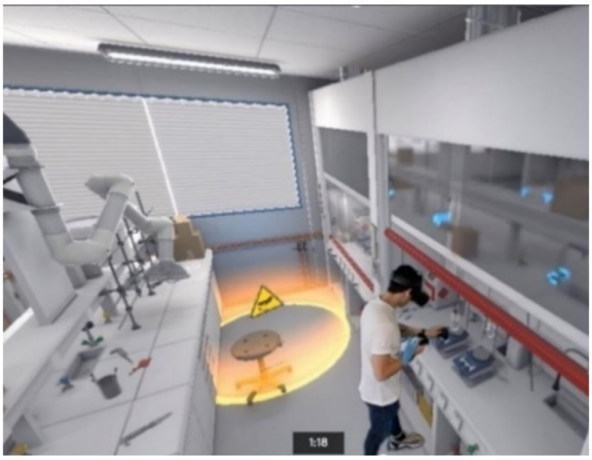

Figure 13: Use of the augmented virtuality facility with a green background (2).
Source: Screenshot from France Immersive Learning.

The class sees its peer learner on the big screen (figure 12), in context in the digital twin. In the inset at the top right of the screen (figure 13), the class views the subjective perspective of the operations performed by the classmate.

In a system like this, and depending on the experience of each learner, peer tutoring is likely to be set up to support the progress of the learner who "goes to the blackboard".

This work was carried out by a multidisciplinary team (chemistry, agri-food, pharmacy) of over 20 professors, educational designers, engineers and technicians from the Conservatoire national des arts et métiers (Le Cnam, Paris, France). The author would like to thank Prof. Maité Sylla-Iyarreta Veitía, who led the group, and the instructional designers on the author's team: Christian Cousquer and Sandrine Dewez. This work is part of the JENII project to design and produce immersive and interactive digital twins for teaching, coordinated by the Arts et Métiers Institute of Technology, with the participation of Le Cnam, CESI and CEA. The JENII project is funded by the Agence Nationale de la Recherche (ANR - ref ANR-21-DMES-0006) as part of the French national call for projects PIA4 DemoES. The duration of the project is four years, starting in November 2021.

1.8. Improving rhetoric skills with VR and AI in a university setting

Corinna Stiefelbauer

In face-to-face classrooms, it is often difficult to simulate realistic presentation scenarios. The implementation of VR opens new ways to specifically help students develop their individual rhetorical skills. The course "Presenting effectively and arguing convincingly" in a Bachelor programme at WU (Vienna University of Economics and Business) piloted such an implementation. VR, in combination with face-to-face teaching methods, addresses the varied requirements of skill development.

Problem definition

It is often difficult to simulate realistic situations in the classroom, such as presentations in front of a large audience. The implementation of a VR application with AI-based evaluation can target this issue and provide a protected space to practice presentation skills.

Pedagogical approach

The teaching and learning method used in the course "Presenting effectively and arguing convincingly" (course teacher: Michael Posch) consists of four phases with feedback and reflection loops:

- Determining the different entry levels of students (face-to-face).
- The first part of the rhetoric training in VR is to simulate a realistic presentation situation to reduce existing fear of presenting and to improve skills related to presenting in individually defined areas (e.g., voice, gestures, eye-contact, etc.). Students practice alone in a protected space.
- Presentation in class in front of the teacher and fellow students with varying levels of difficulty and video-based feedback for self-reflection.
- The second part of the rhetoric training in VR is enabling students to develop their strengths further and mitigate their remaining weaknesses. In addition to oral and video-based feedback, students are provided with detailed evaluations by AI.

Underlying technology

The VR application used was obtained from a commercial provider. Among offers from several providers on the market that offer a comparable tool, WU Vienna selected an application that is GDPR-compliant.

Usually, license fees have to be paid for such tools. If the application is to be used by several users at the same time, several licenses are required. This makes it difficult to scale the use of the application for a larger number of users.

Transferability of the usage scenario

At WU Vienna, seamless learning is an important principle in teaching and learning. It refers to the interweaving of traditional and digital learning environments and techniques, utilising both digital and non-digital didactic elements and formats to craft a unified learning encounter. The pedagogical concept of this course is based on this principle, combining face-to-face elements and digital components such as VR and AI in a meaningful way to create an engaging learning experience. The course was launched in 2023, and its design is constantly being fine-tuned based on evaluations. The usage scenario is evaluated on the basis of a questionnaire sent out to students and feedback from teachers using the technology.

The technology-based concept is intended to serve as best practice and inspiration for transfer to numerous other applications. The virtual rhetoric training can be used in German and in English.

Summary

The course "Presenting effectively and arguing convincingly" focuses on the individual advancement of presentation and argumentation skills of students by means of training and feedback cycles. The integration of VR into the course design has offered students a protected space for practicing. Alternating between face-to-face and VR-based elements and coupling them with various forms of feedback, leads to improved development of competences.

1.9. Inclusive immersive learning

Paraskevi Foti

ARTutor is an AR educational platform developed by Advanced Educational Technologies and Mobile Applications (AETMA) Research Lab at the International Hellenic University since 2016.

ARTutor is available free of charge to all educators and students around the globe in order to help them develop technology-enhanced educational material and improve educational performances and experiences. ARTutor aligns with the "Immersive Education for All" vision, in accordance with the UNESCO initiative "Education for All", which seeks to remove socioeconomic or cultural barriers that limit access to high-end educational technologies and to technology-enhanced learning in general.

Its focus is on adding digital content to traditional educational books and other texts, with the aim of assisting students' independent study and ultimately improving their understanding of the material. The main goals of ARTutor in the field of education can be summarised in the following objectives:

- Maximise students' engagement with the educational material (textbooks).
- Enable teachers with limited IT skills to develop AR books and create highly engaging and immersive educational activities and experiences in the class.
- Implement a single mobile application to enable students to access all the AR books to enhance their study and to promote independent, self-paced distance learning.
- Enable easy interaction with the enhanced digital content of any book using haptic commands to assist even students with movement disabilities.

Where can I use ARTutor?

ARTutor is a domain-independent platform that can be used in many fields, such as publishing, education, marketing, museums, training, treasure hunts, and escape (Lytridis et al. 2018).

Online Training Programme on Immersive Technologies for Education (ImTech4Ed)

ARTutor was introduced and utilised in the short training programme Online Training Programme on Immersive Technologies for Education. It was part of the Erasmus+ funded project Immersive Technologies for Education (ImTech4Ed), which focuses on the application of AR and VR technologies in STEAM education.

The training involved students, researchers, and teachers and was available remotely. It included asynchronous activities (e.g., educational content study, exercises) and a total of five online meetings. It was attended by teachers of different STEAM domains and students from different study programmes (computing, game design, arts, humanities, and social sciences) in universities in three European countries (Cyprus, Greece and Germany). In this way, the innovative content was combined with the possibility of cultivating "21st century skills" concerning creativity and the ability to operate and collaborate in heterogeneous groups (Kazanidis et al. 2018).

Studies have explored the platform's effectiveness in various educational contexts, including teaching Greek mythology through VR and game-based learning, conducting trials of the Acropolis, evaluating a VR educational game for history learning, incorporating ARTutor into museum education, and exploring numerous other valuable applications.

1.10. Designing for immersive learning experiences in VR

Jackie Toal

Approach and conceptual framework

Using VR and AR can assist in developing a way of learning using storytelling and narratives to create connections to facilitate learning (Vaughan-Lee 2019; E-learning 2024). VR offers opportunities to transport a learner into a first-person perspective narrative, where they are active participants fully immersed and engaged in a story, whereby they have a greater sense of agency in constructing their own knowledge and meaning. Learners can explore, engage, manipulate, and interact with objects and characters, allowing them to make sense of the virtual, immersive, and imagined world. This allows learners to contribute to the construction of their knowledge. AR and VR offer more real- time interaction and user control than 2D designs and traditional forms of learning (Vaughan-Lee 2019). This aligns with the principles of Constructivism (Vygotsky) (Negi 2023). Constructivism is how students construct their own meaning and develop their knowledge. Experiential Learning Theory (Kolb) (Morris 2020) will allow students to develop experience, active experimentation and reflection.

Techniques

Designing for presence (Zhang et al. 2020; iMotions 2022) involves placing a learner as the first person in a narrative as a co-author. Presence is the feeling of being physically there, which can engage a user's senses and emotions. For immersive storytelling via multi-sensory experiences, this can include:

- Spatial sounds and audio can be used to sound like the real world, including directionality, distance, and the acoustics of the environment. Sound adds realism and can help direct attention or convey information. "Anne Frank House" (Frank 2018) is a good example of the variety of immersive experiences and sensory tools.
- High-quality visuals and interactive assets that respond to the user, 360-degree-videos, and interaction with avatars. Blue Planet VR (2024) is a good example of the use of high-quality visuals to give the user a more real-world learning experience.
- Environmental elements, virtual imagined worlds, and believable settings. Nature Treks VR (2024) is an interesting example, with a mix of sensory learning to create a feeling of being in nature while enhancing learning.
- Multi-sensory experiences – haptic feedback, touch, and feelings of nature – in VR appeal to a broader range of human senses. Masterworks journey through history is a good example (Masterworks n.d.).
- User experience (UX), intuitive, user -friendly design with affordances (objects that show the user how to interact with the story), signifiers (refer to the actions that can be visual or auditory), and feedback (the user will receive feedback, either auditory or visual) (Lee et al. 2018).

Benefits of learning and enhancing experiences

The benefits of learning involve increased use of empathy and emotional impact. It can be more engaging for learning to place a learner inside a narrative, active rather than passive. Vaughan-Lee (2019) uses immersive storytelling as a pedagogical tool to explore human interest stories, support collaboration, creativity, and critical thinking, and foster cultural awareness. Immersive narratives in 360-degree videos with art are explored in a beneficial way to promote women in STEM (Galvão et al. 2022). Fayda-Kinik (2023) suggests that AR can help learners understand difficult concepts by linking the real world with interactive concepts.

Design techniques and approaches

Examples illustrated below are part of teaching resources in a UX class to help students learn about creating VR experiences, creating user interfaces (UI), and learning how to create interactive objects using some assets from the Unity asset store, the Interaction XR toolkit, and Vuforia.

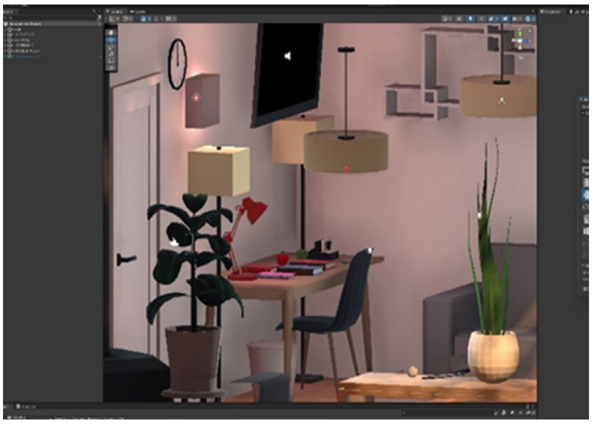

Figure 14: VR room developed with XR Interaction toolkit.
Source: Design created for VR lesson by Jackie Toal.

Figure 15: VR UI in Unity Signifier, affordances.
Source: Design created for VR lesson by Jackie Toal.

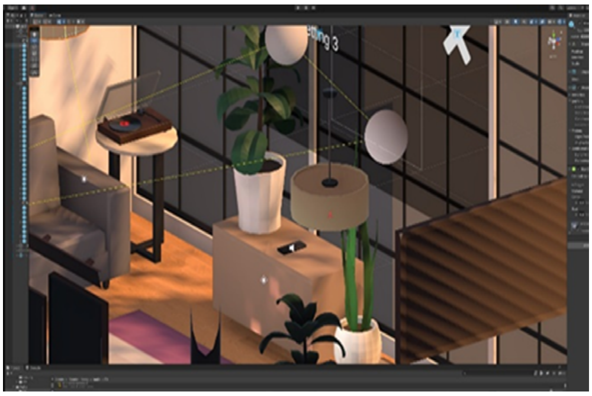

Figure 16: VR room with interactable objects.
Source: Design created for VR lesson by Jackie Toal.

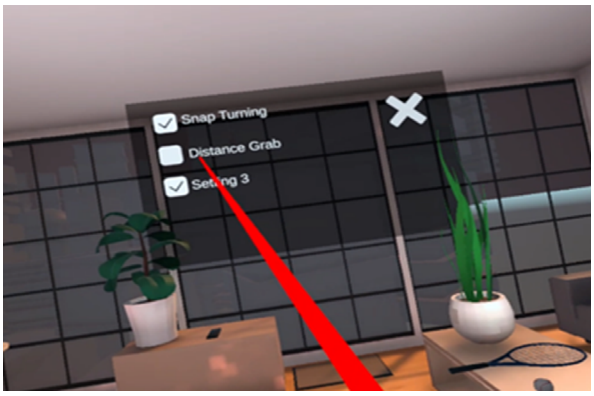

Figure 17: UI Interaction for User control signifier.
Source: Design created for VR lesson by Jackie Toal.

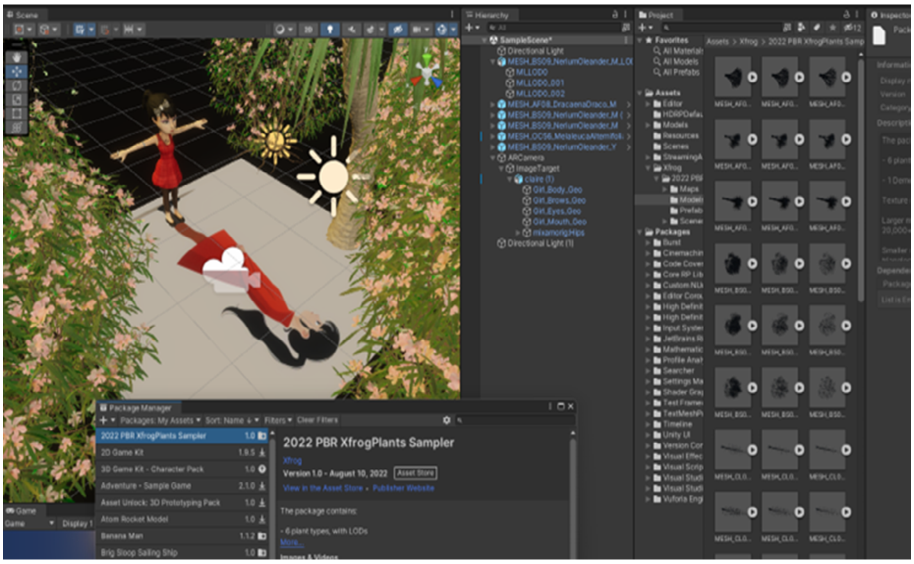

Figure 18: Unity with AR Vuforia.
Source: Design created for VR lesson by Jackie Toal.

Steps to implement

To design for immersive storytelling experiences:

1. Create a user persona.
2. Map the user journey.
3. Storyboard and plan.
4. Consider legal and ethical considerations.
5. Choose appropriate software for the development of VR.
6. Create the design assets for the project either in 3D or 2D.
7. Prototype experiences.
8. Employ user testing to ensure the best user experience and reduce any adverse effects of motion sickness (VR). This can occur if the on screen graphics do not keep pace with users' head, resulting in adverse feelings of nausea.
9. Build and run the final version in a software application.

Tools, benefits, purposes, hints and uses

Asset creation

Using tools such as Autodesk Maya (free with academic email; registration or renewal required each year) or Blender (fully open source) can allow a creator to model and texture assets for VR use. Benefits include the unique creative scope offered by 3D modelling software; limitations include the “steep learning curve”. Readymade assets can be sourced from sites such as Unreal Engine Marketplace, Unity Assets Store, Poly Pizza and SketchFab. Benefits include that they are already created, however some of these may be paid assets, though many are free. One constraint is that, depending on the version of software, a designer may have to reapply the materials. Useful file formats for assets include GLB, FBX, and OBJ. These are appropriate file formats for use with designing for VR. The purposes of these afore mentioned are for content creation for use within immersive designs.

Immersive content prototyping and development tools

For VR and AR development, well-known tools are Unity 3D and Unreal Engine. The examples illustrated above were developed with Unity 3D.

For VR creation in Unity, the use of packages such as the XR Interaction Toolkit can provide good starting points for educators. The Vuforia AR package is beneficial to allow for creating an AR camera, image targets and in Unity to aid in the development of apps.

The benefits of these are that they are well established, and there is a version that is free to use by many users, from novice to advanced. However, they do require a steep learning curve. Alternatives that are more user-friendly and offer versions that involve an easier learning curve include 8th Wall and Zapworks for AR content development. Both offer a free trial period. Immersive VR can also be created with Bezel (now named Bezi) and Figma. Figma will allow for prototyping and creating the graphics; using Bezel, the UI created in Figma can be developed into an immersive experience. Another great alternative is Shapes XR.

GDPR issues/concerns

All these tools require users to sign up, create an account, and provide password details. The process to sign up is intuitive, and there is also a password reset function. Both Unity and Unreal Engine require a user to download and install software. Unreal also requires downloading Epic Games Launcher to install first. In contrast, 8th Wall works in the browser, as do Bezel and Figma.

For educators, there is a wealth of online tutorials and support on the following: VR for Educators forum (Educators in VR 2024), learn Unity pathways and community learning pathways for Unreal. Figma has a wealth of resources, as do 8th Wall and Bezel.

Alignment with the Digital Education Action Plan

This pedagogical technique aligns with the Digital Education Action Plan for digital transformation by contributing some insights on the uses of immersive learning and providing guidance in line with Action 7, "common guidelines for teachers and educators to foster digital literacy and tackle disinformation through education and training" (European Commission 2021).

1.11. Accessibility – universal design for learning and promoting inclusive learning experiences

Dara Cassidy

With immersive virtual learning, as with all teaching and learning activities, a one-size-fits-all approach will not be optimal for all learners. Learners bring a great deal of diversity to their education, in terms of both background and situational factors (El-Khawas 2003). Adopting a universal design approach to the development of immersive virtual learning experiences can help to ensure inclusivity by minimising barriers to full engagement for all learners, regardless of their personal circumstances.

Developed at the Cener for Applied Special Technology, Universal Design for Learning (UDL) is a set of guidelines that can help educators design, select and implement more flexible and inclusive teaching strategies (Meyer et al. 2014). Rooted in learning science and cognitive neuroscience, the UDL framework focuses on the engagement of three different brain networks crucial for learning: the affective, recognition, and strategic networks.

Each network is associated with an overarching principle, which is displayed at the top level of the UDL framework. These principles are further elaborated through three guidelines, each of which is then subdivided into a number of checkpoints. These checkpoints represent the specific strategies and practical suggestions for their implementation.

UDL and immersive virtual learning

The Cognitive-Affective Model of Immersive Learning (CAMIL) identifies six affective and cognitive factors that support the process of learning in immersive virtual reality (IVR) environments: interest, intrinsic motivation, self-efficacy, embodiment, cognitive load, and self-regulation (Makransky and Petersen 2021). By aligning each of these factors with the principles and guidelines outlined in the UDL framework, educators can use UDL checkpoints to design inclusivity into virtual immersive learning experiences. The table below shows the alignment of each CAMIL factor with elements of the UDL framework.

Table 2: CAMIL Factors mapped to UDL principles and guidelines.

CAMIL Factor	UDL Framework
Interest	Principle: engagement Guideline: options for recruiting interest
Intrinsic motivation	Principle: engagement Guideline: options for recruiting interest
Self-efficacy	Principle: action and expression Guideline: options for executive functions
Embodiment	Principle: action and expression Guideline: options for physical action
Cognitive load	Principle: representation Guidelines: options for perception, language and symbols, comprehension
Self-regulation	Principle: engagement Guideline: options for self-regulation

Based on this mapping, the checkpoints within each UDL guideline can be used to provide guidance on inclusive approaches for each CAMIL factor. For example, UDL Checkpoint 7.3, "Minimise Threats and Distractions", underscores the importance of establishing a safe space and provides specific recommendations for achieving this goal. This aligns closely with best practices in simulation (Rudolph et al. 2014) and other forms of immersive learning (Kisfalvi and Oliver 2015), which emphasises the importance of psychological safety in creating an effective learning environment.

1.12. User experience design and evaluation for immersive learning

Jelena Nakić

When students use immersive environments for learning, they expect an experience similar to playing VR games (Cho and Park 2023). Therefore, in the development of immersive learning environments, it is important to not only ensure a good learning experience but also to create a strong sense of gameplay and immersion in the virtual space.

Design guidelines

When developing immersive resources for learning, the primary aim is to enhance the teaching-learning process by boosting motivation and effectiveness. Subsequently, the application creation process involves several key steps (Vergara et al. 2017):

1. Deciding the level of realism needed for each objective, ranging from symbolic to realistic representations.
2. 2Choosing the level of user interaction, encompassing engaged senses (e.g., sight, sound, and touch), and the degree of control and immersion within the virtual environment.
3. Selecting hardware and software tools aligned with the objectives.
4. Modelling the virtual world, designing interactivity, and generating the application.
5. Testing with pilot users to validate achievement of learning objectives and identify areas for improvement, followed by necessary modifications.

This process is illustrated in figure 19.

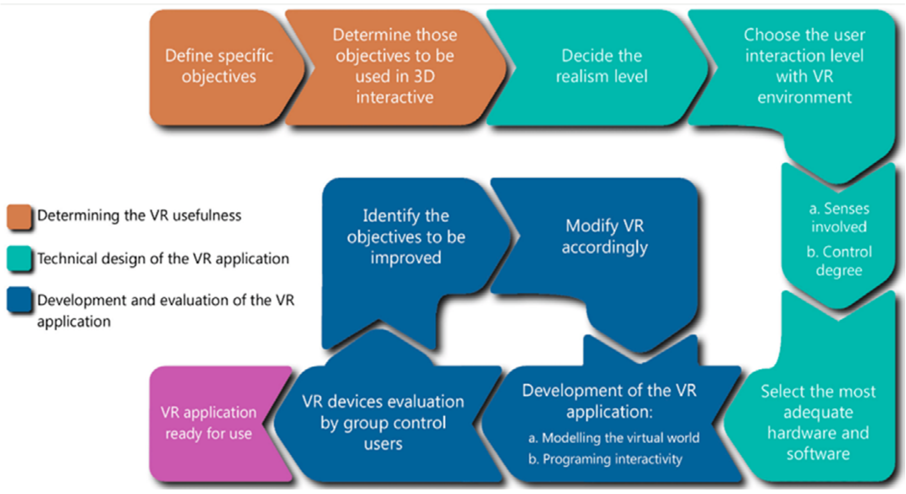

Figure 19: Typical workflow of VR applications development.
Source: Vergara et al. 2017.

In their VR training design guidelines, Shahu et al. (2023) emphasise the importance of making the experience feel real and engaging. This involves ensuring that users can interact naturally with the VR environment, facilitating better learning outcomes. It is also key to design VR training programmes to evolve continuously, incorporating new content and learning methods to sustain user interest and skill development. Another important guideline is to prioritise usability, making VR training accessible to users of all backgrounds by eliminating potential obstacles that could hinder learning.

To achieve the effectiveness and usability of product development, a user-centred design approach is often utilised (Nakić et al. 2019). One of the most effective methods within user-centred design is considered to be participatory design, where typical future application users are involved throughout the development process (Giacobone et al. 2024). Sharing power and decision-making among all participants enables the creation of designs that are more inclusive and democratic, considering various perspectives and expertise (Ampatzidou and Gugerell 2019). This method has proven to be highly effective in the development of immersive learning environments, particularly for students with special needs such as autism (Caruso et al. 2023).

Within the virtual world, in addition to the learning process, assessment can also be integrated. Udeozor et al. (2023) developed the Game-Based Assessment Framework (GBAF) for educators to create assessments for students using video games, VR, or AR. This framework simplifies the process of assessment design by breaking it down into familiar steps for teachers, ensuring alignment between students' learning and the tasks they perform in the game.

Evaluation: usability, pedagogical value, and presence

The key phase in the development of any interactive system is evaluation, encompassing both for effectiveness and usability. Under the effectiveness of digital learning environments, in addition to the technical correctness of the application, we also consider their impact on learning outcomes. For evaluating usability and learning achievements, group testing methods are commonly used, and the best results are shown by combinations of mutually complementary quantitative and qualitative evaluation methods.

A mixed-method approach, proposed by (Granić et al. 2019) integrates various usability testing methods with assessments of educational value to evaluate three-dimensional Virtual Learning Environments (VLEs). This approach focuses on user testing to enhance the design and development of learner-centric solutions. The ScerGUT approach (Scenario-based Group End User Assessment) incorporates quantitative measures such as knowledge acquisition, memorability and subjective satisfaction as important dimensions of usability.

Qualitative data collected during user testing includes demographics, user expertise, subjective feedback, and problem identification by evaluators.

Concerning the ways of obtaining quantitative and qualitative measures, several measuring instruments are used:

- Multichoice questionnaires aimed at getting users' personal information as well as their prior experience and expertise.
- Pretest/post-test is used for measuring acquired knowledge as a measure of educational value.
- A memory test, a questionnaire, is used to determine the number of successfully memorised functions of the system.
- Attitude questionnaires are used for users' subjective evaluation of their learning experience and their satisfaction with the learning environment.
- Semi-structured interviews are used as an instrument for acquiring additional subjective feedback.
- Evaluator's booklet in which the experimenter/evaluator conducting the assessment procedure takes notes, documents, and describes identified problems and fills in any other information related to, for example, the accuracy of task completion and time spent on task performance.

The implementation framework for the ScerGUT method is presented in figure 20.

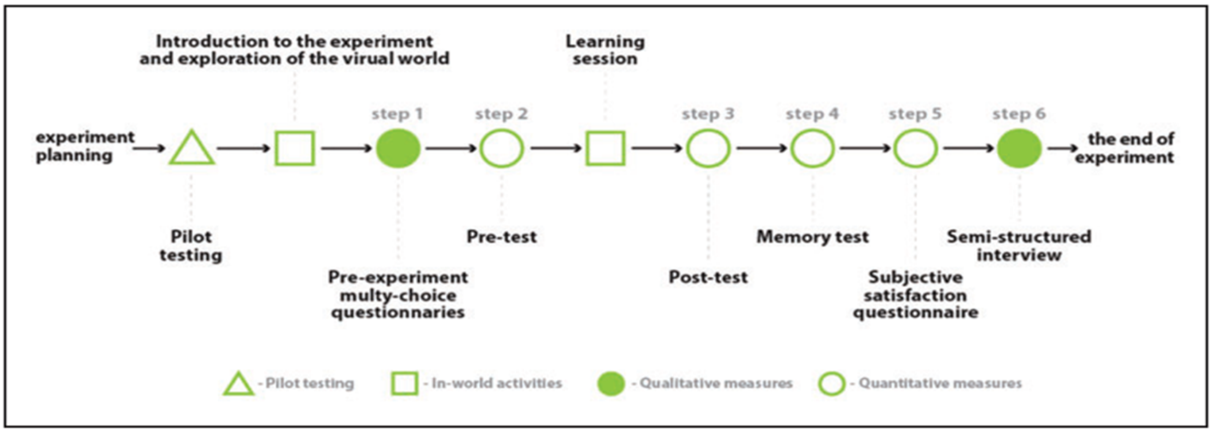

Figure 20: The procedure of Scenario-based Group Usability Testing for 3D virtual worlds. Source: Granić et al. 2019.

This paper also presents a case study utilising this method, specifically its implementation in the evaluation of the 3D multiuser virtual world V-ALERT, developed for learning about internet safety through various learning scenarios (Ntokas et al. 2015). The collaborative environment of the V-ALERT virtual world is illustrated in figure 21.

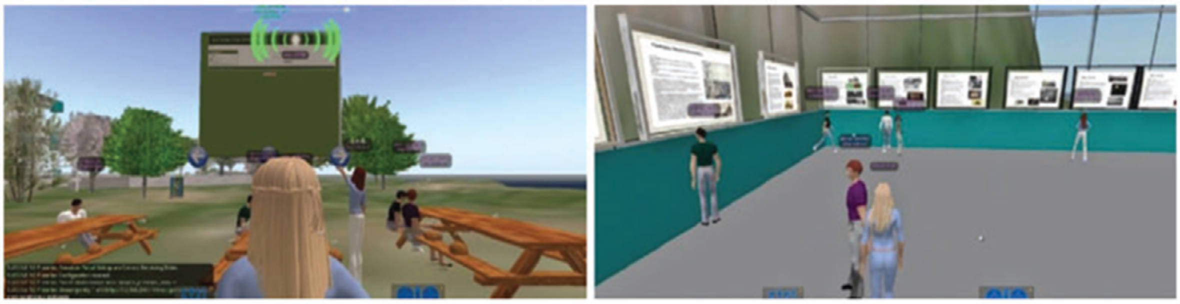

Figure 21: User interface of V-ALERT virtual world.
Source: Granić et al. 2019.

In addition to end-user testing, it is recommended to conduct a comprehensive heuristic evaluation with a team of usability experts, especially those specialising in the human-computer interaction. This process involves usability experts thoroughly examining the interface based on established usability principles and guidelines to identify potential issues or violations. The guideline inspection serves as a complementary method to user testing as it helps to uncover usability problems that might not be apparent from user testing alone.

For effective learning in immersive environments, establishing a sense of presence is essential (Rieger and Risch 2023). Presence in virtual environments encompasses two main dimensions (Granić et al. 2017):

- Involvement in the virtual environment: This refers to a user's ability to concentrate their attention and mental energy on stimuli within the virtual world.
- Sense of immersion: This involves feeling like a part of the virtual environment and perceiving oneself as physically present within it.

The presence can be measured through specially designed questionnaires, such as the Presence Questionnaire, which includes the following five factors (Witmer et al. 2005):

- Involvement: measures the depth of engagement with the virtual environment,
- Adaptation/immersion: assesses how well the virtual world adapts to user actions,
- Interface quality: evaluates the effectiveness of the interface for interaction,
- Distraction: identifies anything that disrupts focus or immersion,
- Sensory fidelity: evaluates the replication of real-world sensory experiences.

Enhancing presence involves optimising these factors to create more compelling and immersive virtual experiences, making users feel more engaged and connected to the virtual world.

1.13. Promoting inclusive immersive reading with AR: school AR

Paraskevi Foti

Augmented Reality (AR) is increasingly making its mark in educational materials, particularly traditional schoolbooks. AR-enhanced books deserve special research attention due to the advantages they offer users. Education is a foundation to equip young people with knowledge and skills. To support this process, teachers have traditionally relied on books as primary educational tool. Historically limited to 2D texts and images, these schoolbooks can now be enhanced with AR to make the learning experience more dynamic and interactive.

AR applications with books

- Fairytale books for pupils
- Painting books (converting paintings into 3D)
- Game cards presenting animals, transportation, etc.

Software for developing AR applications

- Openspace 3D
- Zapworks
- SDK Vuforia (Unity)
- DroidAR

The purpose of school AR

- Applies to something easily accessible (schoolbooks).
- Is available for free.
- Is available to everyone (teachers and students).
- Does not require an internet connection.
- Can be used in the educational process.
- Can be related to specific lessons.

Challenges

- A lot of the developing software had to be paid for.
- The books have specific images (recognition difficulties in identification machine)
- Good programming skills (C# or Java) are required.

Preview of application

Traditional schoolbooks typically feature 2D images printed on paper. AR technology revolutionises this format by presenting users with interactive 3D objects directly on the corresponding page, significantly enhancing their pedagogical value. Examples of 3D objects that can be incorporated into educational processes to facilitate teaching include geometric patterns, ancient monuments and statues, machinery, and more.

- Ability to view videos for better understanding of the experiments being presented in physics, chemistry, and more.
- Easy to use. AR applications are easily accessible on mobile devices eliminating the need for internet browsing or specific software on computers.
- 3D objects within AR applications are adapted with course material, serving to clarify and expand upon topics. It creates an interactive learning environment where the student can observe the 3D objects in their physical space and understand them better.

Finally, it should be mentioned that it is an easy way to upgrade and modernise the material in the books. This approach not only equips students with proficiency in utilising innovative technologies but also does so at minimal expense.

1.14. Summary

Jackie Toal

This chapter provided an overview of pedagogical approaches, techniques and specific tools used in institutions around Europe to enhance learning and teaching practices. These examples show that, to make a difference and have a significant impact on student's learning and to create a disruptive experience, the use of immersive technologies and environments needs to be based on solid pedagogical intentions, objectives, and scenarios.

Far from providing an exhaustive view of possible methods and practices, the aim of the chapter is to explore possible strategies and inspire educators to create their own scenarios that can be implemented in various ways and in the context of an institution, a course, or a learning activity.

In the next chapter, we will be deep diving into examples of implemented best practices in the context of secondary and higher education in European institutions.

References

Alsadoon, H. (2023): The Impact of Gamification on Student Motivation and Engagement: An Empirical Study, Educational Sciences, 50(2), p. 386–396, https://doi.org/10.35516/edu.v50i2.255.

Asay, L. D., Orgill, M. (2010): Analysis of Essential Features of Inquiry Found in Articles Published in The Science Teacher , 1998–2007, Journal of Science Teacher Education, 21(1), p. 57–79, https://doi.org/10.1007/s10972-009-9152-9.

Balog, A., Pribeanu, C. (2016): An Extended Acceptance Model for Augmented Reality Educational Applications, in Neto, F.M., Souza, R. (eds.), Handbook of Research on 3-D Virtual Environments and Hypermedia for Ubiquitous Learning, p. 537-554.

Barreda-Ángeles, M., Hartmann, T. (2022): Psychological benefits of using social virtual reality platforms during the covid-19 pandemic: The role of social and spatial presence, Computers in Human Behavior, 127, 107047, https://doi.org/10.1016/j.chb.2021.107047.

Chintiadis, P., Kazanidis I., & Tsinakos A. (2017): Trials of the Acropolis: Teaching Greek mythology using Virtual Reality and game-based learning, International Conference on Interactive Mobile Communication, Technologies, and Learning, IMCL2017, Thessaloniki, Greece.

Cho, Y., Park, K. S. (2023): Designing immersive virtual reality simulation for environmental science education, Electronics, 12(2), 315, https://doi.org/10.3390/electronics12020315.

Chopra, B., Verma, K., Singhal, S., Singla, U. (2021): Reality Tales: Facilitating User-Character Interaction with Immersive Storytelling, Conference on Human Factors in Computing Systems - Proceedings, p. 2–8, https://doi.org/10.1145/3411763.3451522.

Di Natale, A. F., Repetto, C., Riva, G., Villani, D. (2020): Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research, British Journal of Educational Technology, 51(6), p. 2006–2033, https://doi.org/10.1111/bjet.13030.

Doroudian, S. (2023): Collaboration in Immersive Environments, Challenges and Solutions.

E-Learning (2024): The Future of Learning Revolutionizing Education through VR and AR Integration, https://elearning.adobe.com/2024/04/the-future-of-learning-revolutionizing-education-through-vr-and-ar-integration/ (accessed 03 May 2024).

El-Khawas, E. (2003): The many dimensions of student diversity, in Komives, S. R., Woodard, D. B. J. (eds.), Student services: A handbook for the profession, p. 45-52.

European Commission (2021): Digital Education Action Plan (2021-2027), European Education Area, https://education.ec.europa.eu/focus-topics/digital-education/action-plan (accessed 07 October 2024).

Fayda-Kinik, F. (2023): Augmented Reality in Education: An Overview of Research Trends.

Felkey, A. J., Dziadula, E., Chiang, E. (2023): Competition, Motivation, and Student Engagement, AEA Papers and Proceedings, 113, p. 508-513, https://www.aeaweb.org/articles?id=10.1257/pandp.20231047.

Furtak, E. M., Seidel, T., Iverson, H., Briggs, D. C. (2012): Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching: A Meta-Analysis, Review of Educational Research, 82(3), p. 300–329, https://doi.org/10.3102/0034654312457206.

Galvão, D. S., Biazzi, R. B., de Morais, G. C., & Miranda, C. R. (2022): Women in science: a Brazilian experience through immersive narratives in 360° videos, International Journal of Science Education, Part B, 12(4), p. 309-327, https://doi.org/10.1080/21548455.2022.2076293.

Gazcón, N., Castro, S. (2015): ARBS: An Interactive and Collaborative System for Augmented Reality Books, in De Paolis, L. T., Mongelli, A. (eds.), Augmented and Virtual Reality: Second International Conference, AVR 2015, p. 89–108, https://doi.org/10.1007/978-3-319-22888-4_8.

Granić, A., Nakić, J., Ćukušić, M. (2017): Preliminary Evaluation of a 3D Serious Game in the Context of Entrepreneurship Education, in Proceedings of 28th Central European Conference on Information and Intelligent Systems (CECIIS), University of Zagreb, Croatia.

Granić, A., Nakić, J., Marangunić, N. (2019): Scenario-based group usability testing as a mixed methods approach to the evaluation of three-dimensional virtual learning environments, Journal of Educational Computing Research, 58(3), p. 616–639, https://doi.org/10.1177/0735633119859918.

Gröppel-Wegener, A., Kidd, J. (2019): Critical Encounters with Immersive Storytelling, https://doi.org/10.4324/9780429055409.

Huseinović, L. (2023): The Effects of Gamification on Student Motivation and Achievement in Learning English as a Foreign Language in Higher Education, MAP Education and Humanities, 4, p. 10–36, https://doi.org/10.53880/2744-2373.2023.4.10.

Institute for Experiential Learning (n.d.): What Is Experiential Learning?, https://experientiallearninginstitute.org/resources/what-is-experiential-learning/ (accessed 29 Novmeber 2022).

Kazanidis, I., Palaigeorgiou, G., Chintiadis, P., Tsinakos, A. (2018): A Pilot Evaluation of a Virtual Reality Educational Game for History Learning, in ECEL 2018 17th European Conference on e-Learning, p. 245.

Kisfalvi, V., Oliver, D. (2015): Creating and maintaining a safe space in experiential learning, Journal of Management Education, 39(6), p. 713-740.

Kolb, David A. (1984): Experiential Learning: Experience as the Source of Learning and Development, Englewood Cliffs, N.J.

JENII (2023): Teaching with immersive and interactive digital twins, JENII White Paper, p. 194-202, https://reliam.ensam.eu/items/b5cbc1ac-ac22-4622-8068-908b974cae77 (accessed 03 May 2024).

Lee, J., Bang, J., Suh, H. (2018): Identifying Affordance Features in Virtual Reality: How Do Virtual Reality Games Reinforce User Experience? Paper presented at the Augmented Cognition: Intelligent, p. 383-394.

Lippmann, M. (2021): Inquiry-Based Learning in Psychology, in Zumbach, J., Bernstein, D., Narciss, S., Marsico, G. (eds.), International Handbook of Psychology Learning and Teaching, pp. 1–30, https://doi.org/10.1007/978-3-030-26248-8_59-3.

Luarn, P., Chen, C., Chiu, Y. (2023): The Influence of Gamification Elements in Educational Environments, International Journal of Game-Based Learning (IJGBL), 13(1), p. 1-12, http://doi.org/10.4018/IJGBL.323446.
Lytridis, L,Tsinakos, A, & Kazanidis, I., (2018): ARTutor. An Augmented Reality Platform for Interactive Distance Learning, Educ. Sciences, 8(6), doi:10.3390/educsci8010006.

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(3), p. 937-958.

Matovu, H., Ungu, D.A. K., Won, M., Tsai, C., Treagust, D. F., Mocerino, M., Tasker, R. (2023): Immersive virtual reality for science learning: Design, implementation, and evaluation, Studies in Science Education, 59(2), p. 205-244, https://doi.org/10.1080/03057267.2022.2082680.

Meyer, A., Rose, D. H., Gordon, D. (2014): Universal design for learning: Theory and practice.

Morris, T. H. (2020): Experiential learning – a systematic review and revision of Kolb's model, Interactive Learning Environments, 28(8), p. 1064-1077, https://doi.org/10.1080/10494820.2019.1570279.

Moser, I., Hlosta, M., Bergamin, P. B., Ramnarain, U., Van Der Westhuizen, C., Penn, M., Mdlalose, N., Pila, K., Ogegbo, A. (2024): Approximating eye gaze with head pose in a virtual reality microteaching scenario for pre-service teachers. Joint Proceedings of LAK 2024 Workshops Co-Located with 14th International Conference on Learning Analytics and Knowledge (LAK 2024), CEUR Workshop Proceedings (CEUR-WS), 3667, p. 272–283, https://ceur-ws.org/Vol-3667/LAVRLAK24_paper_3.pdf.

Nakić, J., Burčul, A., Marangunić, N. (2019): User-centred design in Content Management System Development: The case of emasters, International Journal of Interactive Mobile Technologies (iJIM), 13(08), 43, https://doi.org/10.3991/ijim.v13i08.10727.

Negi, S. (2020): Constructivist Approach of Vygotsky for Innovative Trends in Learning and Teaching, International Journal of Advanced Academic Studies, 2(1), p. 349-353.

Ntokas, I., Maratou, V., Xenos, M. (2015) : Usability and Presence Evaluation of a 3D Virtual World Learning Environment Simulating Information Security Threats, in Proceedings of 2015 7th Computer Science and Electronic Engineering Conference (CEEC), University of Essex, UK.

Obae, C., Alkhayat, A. (2023): Language Learning Pedagogical Affordances of the Metaverse, Conference Papers, https://tccpapers.coe.hawaii.edu/archive/2023/Obae.pdf (accessed 07 October 2024).

Ogegbo, A. A., Penn, M., Ramnarain, U., Pila, O., Van Der Westhuizen, C., Mdlalose, N., Moser, I., Hlosta, M., Bergamin, P. (2024): Exploring pre-service teachers' intentions of adopting and using virtual reality classrooms in science education. Education and Information Technologies, https://doi.org/10.1007/s10639-024-12664-5.

Paoli, K., Otmanine, I. (2022): La formation à distance, résolument ? Learning Experience of Graduate Students in an Online Accounting Course Using Desktop VR under the Light of the Activity Theory, https://www.canal-u.tv/chaines/cned/modeles-pratiques-et-configurations-pedagogiques/educational-models-configurations-and (accessed 7 October 2024).

Paulsen, L., Dau, S., Davidsen, J. (2024): Designing for collaborative learning in immersive virtual reality: a systematic literature review, Virtual Reality, 28(1), p. 63, https://doi.org/10.1007/s10055-024-00975-4.

Penn, M., Van der Westhuizen, C., Ogegbo, A., Mdlalose, N., Pila, K., Hlosta, M., Moser, I., Bergamin, P. (2024): Evaluating Pre-service Teachers' Science Teaching Practices in a Virtual Reality Classroom Using a Learning Analytics Spectator View. Companion Proceedings 14th International Conference on Learning Analytics & Knowledge (LAK24), p. 236–238, https://www.solaresearch.org/wp-content/uploads/2024/03/LAK24_CompanionProceedings.pdf (accessed 07 October 2024).

Posch, M. (2023): Effektiv präsentieren und überzeugend argumentieren: Integration von Virtual Reality zur individuellen Förderung sozialer Kompetenzen, Atlas der guten Lehre, https://gutelehre.at/projekt?tx_gutelehre_default%5Baction%5D=show&tx_gutelehre_default%5Bcontroller%5D=Project&tx_gutelehre_default%5Bproject%5D=1905&cHash=5751c9ca7804b43fd837b7688ab90a37 (accessed 24 April 2024).

Radianti, J., Majchrzak, T. A., Fromm, J., Wohlgenannt, I. (2020): A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & Education, 147, 103778, https://doi.org/10.1016/j.compedu.2019.103778.

Ramnarain, U., Schuster, D. (2014): The Pedagogical Orientations of South African Physical Sciences Teachers Towards Inquiry or Direct Instructional Approaches, Research in Science Education, 44(4), p. 627–650, https://doi.org/10.1007/s11165-013-9395-5.

Rieger, M. B., Risch, B. (2023): How to maximise spatial presence: Design guidelines for a virtual learning environment for school use. IEEE Transactions on Visualization and Computer Graphics, 29(5), p. 2517–2526, https://doi.org/10.1109/tvcg.2023.3247111.

Rudolph, J. W., Raemer, D. B., Simon, R. (2014): Establishing a safe container for learning in simulation: the role of the presimulation briefing, Simulation in Healthcare, 9(6), p. 339-349.

Sin, A. K., Zaman, H. B. (2010): Live Solar System (LSS): Evaluation of an Augmented Reality Book-Based Educational Tool, 2010 International Symposium on Information Technology (ITSim), 1, p. 1-6, http://dx.doi.org/10.1109/ITSIM.2010.5561320.

Shahu, A., Kinzer, K., Michahelles, F. (2023): Enhancing professional training with single-user virtual reality: Unveiling challenges, opportunities, and design guidelines, Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia, https://doi.org/10.1145/3626705.3627791.

Stiefelbauer, C., Ghoneim, A., Oberhuemer, P., Vettori, O. (2023): Verschränkte Lernwelten: physisch, virtuell, seamless, Zeitschrift für Hochschulentwicklung, 18 (Sonderheft Hochschullehre), p. 159–179, https://doi.org/10.3217/zfhe-SH-HL/09.

Stiefelbauer, C. Janko, M. (2023): Innovating Teaching and Learning with Immersive Technologies at WU Vienna, in Bastiaens, T. (ed.), Proceedings of EdMedia + Innovate Learning, Vienna, Association for the Advancement of Computing in Education (AACE), p. 1051-1054, https://www.learntechlib.org/primary/p/222613/ (accessed 03 May 2024).

Turan, S. (2021): Pre-Service Teacher Experiences of the 5E Instructional Model: A Systematic Review of Qualitative Studies, Eurasia Journal of Mathematics, Science and Technology Education, 17(8), em1994, https://doi.org/10.29333/ejmste/11102.

Tzortzoglou F., Sotiris Georgiou S., Spyrou S., Alivizos S. (2018): Creation and evaluation of an augmented reality application for the enrichment of a school textbook in the Proceedings of the 11th Panhellenic and International Conference “ICT in Education”.

Udeozor, C., Chan, P., Russo Abegão, F., Glassey, J. (2023): Game-Based Assessment Framework for virtual reality, augmented reality and digital game-based learning, International Journal of Educational Technology in Higher Education, 20(1), https://doi.org/10.1186/s41239-023-00405-6.

Vaughan-Lee, C. (2019): The Power of Immersive Storytelling: A tool for transformative learning, Childhood Education, 95(3), p. 23–31, https://doi.org/10.1080/00094056.2019.1616466.

Vergara, D., Rubio, M., Lorenzo, M. (2017): On the design of Virtual Reality Learning Environments in engineering, Multimodal Technologies and Interaction, 1(2), 11, https://doi.org/10.3390/mti1020011.

Vygotsky, L. S. (1978): Mind in Society: The Development of Higher Psychological Processes, Cambridge, MA, Harvard University Press.

Witmer, B. G., Jerome, C. J., Singer, M. J. (2005): The Factor Structure of the presence questionnaire, Presence: Teleoperators and Virtual Environments, 14(3), p. 298–312, https://doi.org/10.1162/105474605323384654.

Zhang, H., Yu, L., Ji, M., Cui, Y., Liu, D., Li, Y., Liu, H., Wang, Y. (2020): Investigating high school students' perceptions and presences under VR learning environment, Interactive Learning Environments, 28(5), p. 635-655, https://doi.org/10.1080/10494820.2019.1709211.

PART 2

Best practices in the context of immersive learning

2. Best practices in the context of immersive learning

Jackie Toal

The following are some innovative real- world examples of best practices that have been shared by experienced professionals working within education and digital education. These encapsulate a range of immersive technologies and show diversity within a European digital education context.

2.1. Immersive technology as an expression channel at ORT University in Uruguay

Cristina Obae

At ORT University in Uruguay, VR is used as a means of artistic expression in the Design, Art and Technology Bachelor's degree programme. Since 2018, Professor Fabián Barros Andrade is the director of this degree programme that he created. He immerses his students every year in VR spaces designed by himself and his team in Spatial and other environments such as Minecraft or VR Chat, encouraging them to create artistic experiences that challenge the limits of imagination and bring creativity to a whole new level. It is a completely different form of art, a 3D one that you need to live, experience, get immersed in, and be able to understand. It is also another form of digital education, innovative at the level of others promoted by the EDEH.

One of the biggest challenges is interacting with people who have never participated in virtual experiences or maintaining participants' attention for periods of more than 20 minutes. To do this, it is necessary to design alternative experiences to traditional education.

Figure 22: Uruguay Immersive Learning (1).
Source: Fabián Barros Andrade.

Figure 23: Uruguay Immersive Learning (2).
Source: Fabián Barros Andrade.

Figure 24: Uruguay Immersive Learning (3).
Source: Fabián Barros Andrade.

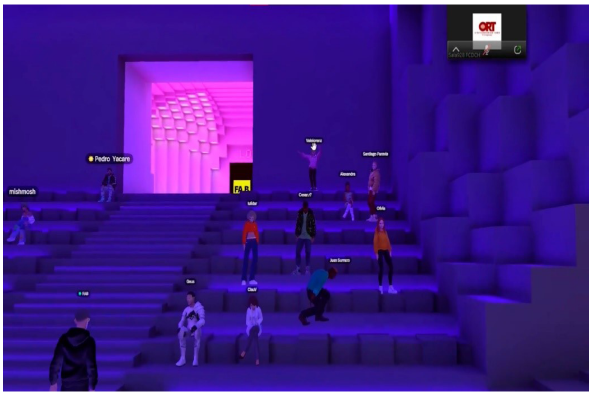

Figure 25: Uruguay Immersive Learning (4).
Source: Fabián Barros Andrade.

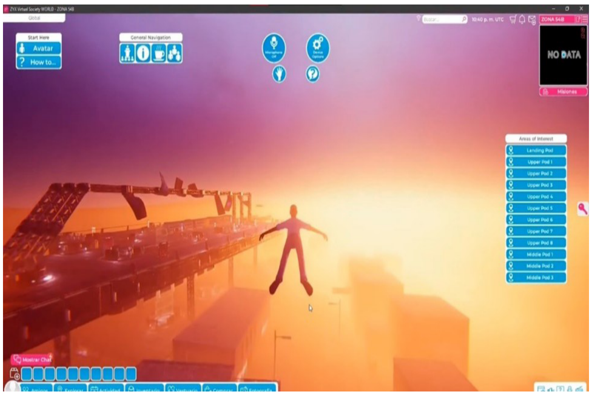

Figure 26: Different VR teaching activities (1).
Source: Fabián Barros Andrade.

Figure 27: Different VR teaching activities (2).
Source: Fabián Barros Andrade.

Figure 28: Different VR teaching activities (3).
Source: Fabián Barros Andrade.

2.2. Immersive language learning classes

Cristina Obae

At an online high school, language learning classes were transformed into immersive experiences by adapting the existing French curriculum to be taught in social VR environments. Taking as a starting point a 2D curriculum built upon the Arizona State University's French standards and the school's requirements for both asynchronous and synchronous work hours, students engage in asynchronous activities via a 2D Learning Management System (LMS). However, the synchronous meetings were taking place in VR. Different social VR apps were used for this purpose such as Engage, Frame VR, and Immerse VR depending on the learning objectives of each synchronous French class. Within these VR environments, students practice all language skills, including listening, speaking, reading, and writing. Students access the learning spaces via VR headsets or computer. Furthermore, AI Non-Player Characters (NPCs) are integrated to provide students with additional support and information on grammar topics.

Figure 29: Student (green avatar) using AI NPC (white avatar) to learn conjugation of French past tense verbs in FrameVR. Source: FrameVR.

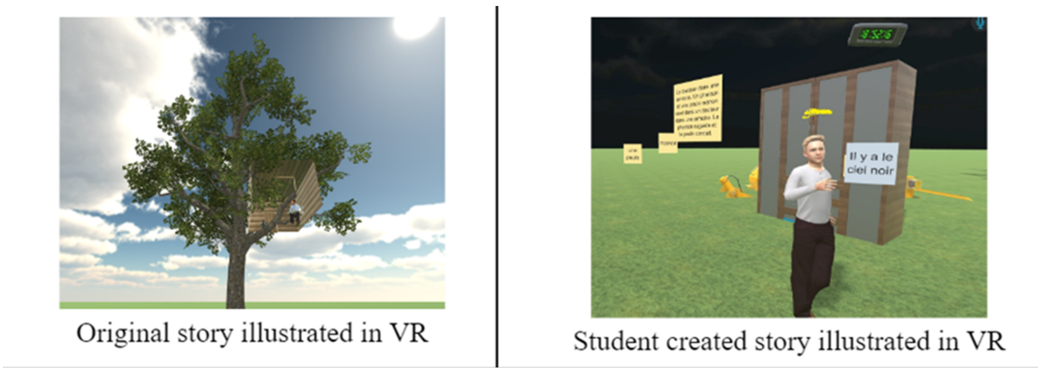

Figure 30: Beginners' students doing a reading comprehension in ENGAGE. Source: ENGAGE.

After only 3 classes of French students were engaged in a VR learning comprehension activity using the ENGAGE VR app. As figure 30 (left part) illustrates, the story was illustrated in the VR space to support understanding of the setting. After orally answering the comprehension questions, students move on to a writing task: creating their own story. On the right is an example of a student story written down and illustrated in the VR environment by the student.

2.3. Extended reality (XR) for immersive arts and cultural learning

Filomena Miguel

Extended reality (XR) is also useful to teach art, history, and cultural heritage in an immersive way. Incorporating AR and VR technologies into educational settings brings up new opportunities for engaging, empathetic, and interactive instructions. These technologies offer a unique chance to immerse students in historical contexts, promote a deeper appreciation of cultural heritage, and improve digital literacy skills, making them important resources for modern educators. Google Arts & Culture uses AR and VR technologies to make art, history, and cultural heritage more accessible and engaging to global audiences. This project attempts to close the gap between students and cultural heritage by improving its accessibility and interaction. Users may engage with historical locations, artworks, artefacts, and many others by using its AR function to examine details in great depth and observe the objects at full scale.

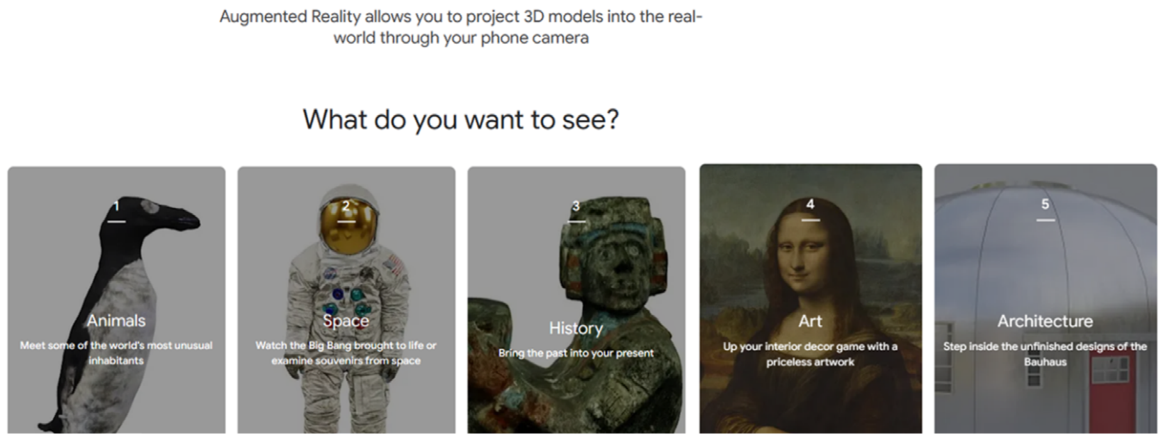

Figure 31: Printscreen from the Google Arts & Culture webpage.
Source: Google Arts & Culture.

On the other hand, Google Arts & Culture VR videos function as a dynamic teaching tool that lets students virtually explore and immerse themselves in a variety of scenarios. Users can take part in 360-degree tours through cultural locations and historical events.

Teacher Becky Cottrell, who is a Ph.D. Senior Lecturer of Spanish, uses Google Arts and Culture in her classes to incorporate cultural and linguistic content into her online and face-to-face elementary-level classes at the university. Using Google Arts & Culture, instructors can virtually send students to renowned museums to investigate cultural objects and artistic representations. In addition, the platform provides a variety of interactive elements, such as thematic collections, to let students engage with art and cultural artifacts. This article suggests techniques for combining these virtual experiences into language classrooms, including activities customised to various levels of language skill. This approach helps to create a more engaging and immersive learning experience for her students.

Anne Frank House VR is a VR tour that allows users to explore Anne Frank's hiding place, providing students with a more realistic understanding of Anne Frank's experience and the historical context of her diary (accessed via Meta Quest equipment).

Figure 32: Picture from "Anne Frank House" VR experience (Meta Store).
Source: Anne Frank Foundation.

Mulders (2023) explored the impact of VR on learning, focusing on 132 middle school students' experience with Anne Frank's hiding place simulation. It compares desktop VR (DVR) and head-mounted display VR (HMD-VR) across two learning approaches: explorative and expository. Regarding the overall significance of the Anne Frank VR House application to enhance cognitive and affective learning, the following conclusion may be drawn:

> *Across all experimental conditions, there is an increase in knowledge and perspective-taking into Anne Frank's situation. Considering the evaluation of the application, high means and low dispersion are detected, resulting in high satisfaction and a high tendency to recommend. Thus, the Anne Frank VR House seems to be conducive to middle school students, no matter which VR technology is used to transport the learning content. (Mulders 2023)*

2.4. VR labs science education

Filomena Miguel

Another area that can be enhanced through the use of VR is the use of VR labs in science education. VR labs seek to democratise science education by providing virtual laboratory simulations that overcome the limitations and costs associated with physical lab spaces and resources. These initiatives can enhance the learning of physics and chemistry, among others, by transforming abstract concepts into tangible, interactive virtual experiments.

VR experiences, which are used in a number of educational contexts, enable students to participate in virtual experiments, making learning more engaging and productive. Educators can include these tools in their science curricula, giving students simple access to hands-on learning opportunities. This approach not only increases participation and knowledge of scientific principles, but it also provides a safe atmosphere for conducting experiments.

Futuclass Education in VR is an Estonian educational platform that aims to engage students in immersive science lessons with a focus on chemistry and physics. The hands-on VR classes enable students to explore concepts at their own pace, actively engage with content, and receive immediate feedback, thereby improving the learning process and retention.

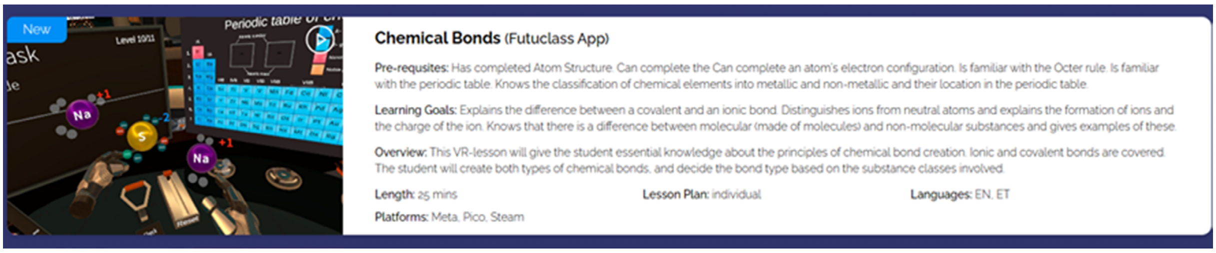

Figure 33: Screenshot from Futuclass Education in VR.
Source: Futuclass Education 2024.

Teacher Emma Abatte (2023) from Liceo Scientifico A. Diaz Caserta, Italy, emphasises the potential of immersive technologies to transform traditional teaching methods and provide personalised learning experiences. She discusses an action research study on the impact of VR and 360° laboratories on STEM education. The study used an action research approach with 100 upper secondary students between the ages of 14 and 15, including those with learning disabilities. Findings suggest VR and 3D labs are effective learning tools, increasing motivation, collaboration, and retention of information.

Another study on the impact of a VR activity on undergraduate students' learning of chemistry concepts, such as naming elements and compounds, identifying atomic properties, and balancing chemical equations is from Donnelly-Hermosillo (2023). It emphasises the potential of VR for enhancing science education and addresses the challenges of integrating VR technology in classrooms.

Despite the benefits, challenges such as the requirement for VR equipment, reliable internet access, and the need for technical support for setup and integration remain. By increasing access to science education, these efforts help to integrate digital tools into education, opening the way for a more engaging and accessible learning experience for students all around the world.

2.5. Island of memory: a project to develop empathy through an immersive experience

Rossana Latronico

The Island of Memory is an Eduverse (educational Metaverse) that tells the story of the Shoah, with particular reference to the Nazi extermination camp Auschwitz-Birkenau, and represents the tribute of students, teachers and the leader of ISIS Europe in Pomigliano d'Arco, Italy to all those who lost their lives there.

Every aspect of the Island of Memory, including the collection of sources, the development of texts and videos, the immersive environment that hosts the story, the editing and development of the virtual path through the extermination camp, the creation of digital artwork, and the restoration of vintage photos from black and white to colour, were carefully processed, even during the lockdown, by the students of ISIS Europa in Pomigliano d'Arco, under the guidance of four teachers.

These efforts extended well beyond traditional teaching hours, involving engagement through webinars held on the Zoom and Meet platforms, with two or three remote sessions each week.

This work brings together the content of three Web portals (la memoria rende liberi, la settimana della memoria and i giorni della memoria), reflecting the research and development work of approximately 80 students over a span of four years. Their accomplishments include:

- shooting hundreds of photographs, including 360-degree photographs, taken in the places covered by the story;
- conducting extensive research for reliable sources across the web and within the historical archives of the Auschwitz-Birkenau Museum and Memorial;
- undertaking studies, in-depth analysis, reflections, comparisons, and writing over a hundred pages of entirely original texts (during the project phase 2020-2021);
- designing and producing over 40 live-streamed interviews (2022, 2023) with survivors of Nazi camps, as well as second- and third-generation witnesses, intellectuals, philosophers, journalists, and artists;
- creating original pictorial and digital works;
- transforming and colouring photographic materials taken from the historical archives of the Auschwitz-Birkenau Museum and Memorial;
- creating digital and immersive timelines;
- creating approximately 20 informative videos.

The preparation, spanning approximately 12 months and the meticulous planning involved in every activity focused on the following fundamental aspects:

1. User experience: ensuring fluid and well-structured experience to visitors to understand the path without getting lost. In addition, within the chosen web platform for the virtual world development, each student is "identified" by an avatar resembling them, enhancing personal connection.
2. Multimedia integration: designing and producing all the content within the environment, integrating different media depending on the objective (including audio, video, images, presentations, etc.).
3. Accessibility: implementing a hybrid approach, instead of focusing on one device type, to ensure content accessibility for users utilising various devices such as computers, smartphones, tablets, monitors, immersive classrooms, and even VR headsets.

Used tools

1. Collaboration and communication: Google Meet, Zoom, Google Classroom, WhatsApp
2. Digital production: Spatial.io, Holobuilder, Sketchfab, Camtasia Studio, Adobe Media Encoder, Audacity, Adobe Photoshop, Photopea
3. DigComp 2.2 and DigCompEdu: The whole project has been structured in line with the skills of DigComp 2.2 to shape a teaching system that allows students to effectively exercise digital citizenship. To guide the work of teachers, DigCompEdu's framework of competencies was fundamental.

Activated skills

- Transversal: critical thinking, problem solving, analysis and interpretation of information, design thinking and creative thinking;
- Digital literacy: proficiency in emerging technologies, foundational digital skills, creation of immersive environments, production or editing of multimedia content;
- Humanities: reading and interpreting historical texts and sources, contextualising historical events, storytelling, and effective written communication;
- Collaborative and emotional: collaboration and team building, adaptability, effective communication, self-regulation and motivation, empathy and sensitivity, stress management;
- Citizenship awareness: remote collaboration, selection and evaluation of information, digital identity, privacy, data protection, online ethical conduct.
- Historical validation: collaboration with the historian Mario Rovinello and the Campania Institute for the History of the Resistance, Anti-Fascism, and the Contemporary Age "Vera Lombardi" along with

Professor Marcello Pezzetti, a world-class expert and consultant to Roberto Benigni and Steven Spielberg in their films on the Shoah, ensuring the historical validation of the virtual story.

- Prestigious collaborations: received contributions of Italian actor and director Giulio Base, who voiceovers for videos and main narratives, and musician Mario Fasciano, who composed and performed the soundtrack of the “immersive work”.
- Exclusive interviews: held with Sami Modiano, Eva Schloss (Anne Frank’s half-sister), Kitty Braun Falaschi.
- Localisation: The entire work “Memory Makes You Free” has been localised in English.

The result is unique, multifaceted, and articulated. Never before has the story of the Shoah been narrated in this manner by a group of students, proving that digital technologies such as the Eduverse and VR can adapt to educational and historical dissemination needs, without distortion. These tools offer significant added value in terms of student motivation, enthusiasm, and engagement, essential for reshaping educational paradigms and fostering deeper levels of learning.

To access the virtual environment, simply type the URL www.isoladellamemoria.it into any browser, wait for the virtual world to load, then use a ready-made avatar or create your own. Once this is done, it is possible to explore the museum environment, enter the virtual itinerary that allows you to visit the Auschwitz-Birkenau extermination camp, explore and discover the historical images in colour, browse through the documents, and watch the videos.

Referent teachers:

- Roberto Castaldo: computer science teacher, creator and coordinator of the project, digital animator and expert trainer of educational innovation (ISIS Europa of Pomigliano d’Arco)
- Angela Schisa: Law and Economics Teacher, ISIS Europa of Pomigliano d’Arco
- Anita Pascale: Multimedia Design Teacher, ISIS Europe in Pomigliano d’Arco
- Krizia Aiese: English language Teacher, ISIS Europa of Pomigliano d’Arco

Figure 34: Entrance to the virtual museum.
Source: Isola della memoria.

Figure 35: Inside the virtual museum.
Source: Isola della memoria.

Figure 36: Artwork the virtual museum.
Source: Isola della memoria.

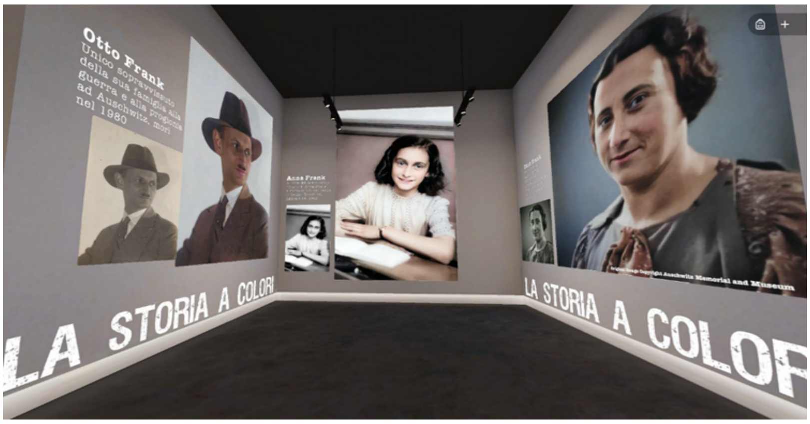

Figure 37: Information on Anne Frank and her parents in the virtual museum. Source: Isola della memoria.

Figure 38: Information on Sami Modiano in the virtual museum. Source: Isola della memoria.

2.6. Virtual field trips through storyworlds

Salvatore Mica

Lyfta is an educational platform that provides virtual field trips through its "storyworlds". These virtual experiences offer affordable and accessible journeys to various destinations worldwide. Through narratives, storylines and interactive content, the solution aims to broaden students' horizons and expose them to diverse cultures, perspectives, and opportunities without physically traveling. By transcending traditional boundaries of education, this immersive learning solution seeks to inspire and empower learners, fostering curiosity, empathy, and global awareness for life.

What are storyworlds?

This learning solution is an educational platform. The virtual experiences allow students to explore different cultures, environments, and stories. The platform provides immersive and interactive learning experiences designed to engage students and broaden their understanding of the world. It aims to inspire curiosity, empathy, and global awareness among learners by presenting them with diverse narratives and perspectives.

Benefits

Boost student engagement: This immersive learning solution captivates students by transporting them beyond their daily environments, encouraging exploration of the world. An impressive 94% of teachers affirm that students find the experience "engaging" or "very engaging". By resonating emotionally with students, additionally, the use of this product ignites stimulating discussions, thereby enhancing classroom engagement. Through authentic human narratives, this learning experience in the classroom introduces students to diverse cultures and perspectives, fostering the accumulation of knowledge and cultural understanding. This immersive experience not only educates but also enriches students' cultural capital, preparing them for a globally interconnected world.

Plan lessons quickly and easily: Lyfta's teacher platform provides educators with access to a wide range of interactive lesson plans and assemblies covering various topics. The platform is designed to be user-friendly, allowing teachers to easily navigate the content by curriculum subject, key stage, theme, or UN Sustainable Development Goals. The lesson and assembly plans offered are adaptable and can be customised to meet the specific needs of each school, ensuring relevance and effectiveness in the classroom. With Lyfta, educators are equipped with the tools necessary to deliver engaging and impactful lessons that connect with students.
Teach complex topics: Lyfta's storyworlds serve as a potent avenue for broaching challenging subjects with children, including loss, resilience, stereotypes, and inequality. Through uplifting human narratives, Lyfta cultivates character and values in young learners. Furthermore, intricate topics like sustainability and global citizenship are presented in an understandable and relatable manner, fostering deeper comprehension and empathy. With Lyfta, educators can seamlessly address complex issues while instilling essential life skills and fostering a sense of global responsibility in students.

Support learning: The learning platform's intuitive student interface seamlessly navigates students through each lesson, accommodating a variety of teaching approaches including whole-class, face-to-face, blended, teacher-led, independent, and remote learning. Whether in the classroom or at home, students can easily access their lessons using a laptop, PC, or tablet. With Lyfta, learning becomes flexible and accessible, empowering students to engage with the curriculum in a manner that suits their individual needs and preferences.

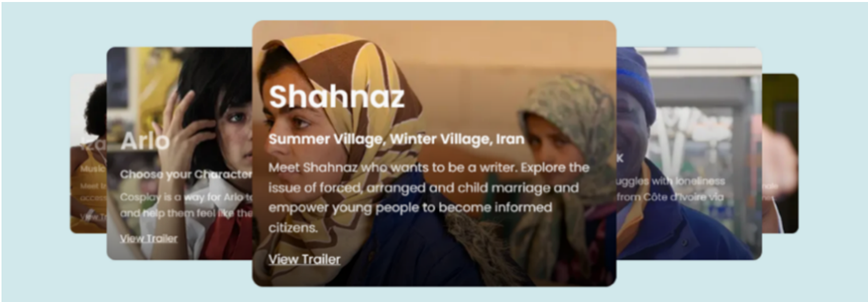

Figure 39: Lyfta's storyworlds.
Source: Lyfta 2024.

Figure 40: Lyfta in the classroom.
Source: Lyfta 2024.

2.7. VR for special needs children's education

Salvatore Mica

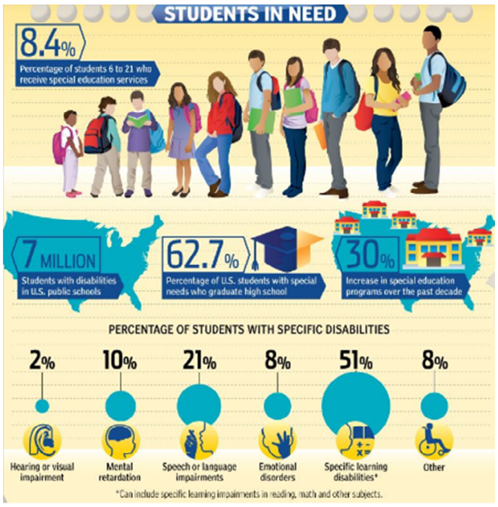

Figure 41: Students in need, digital frontier.
Source: Digital Frontier 2024.

Virtual reality for special integration of technology in classrooms presents numerous advantages for students with disabilities. Special needs teachers can now engage their students more comprehensively through assistive technologies, thereby enhancing the classroom environment and keeping up with technological advancements that benefit their students.

Using immersive learning comes with many advantages for special needs students. For students with special needs such as ADHD or learning disabilities, immersive learning experiences can help maintain focus and attention, leading to improved learning outcomes. For students with anxiety disorders or those who struggle with social interaction, VR simulations can provide a low-pressure environment to develop skills and build confidence.

Customisation and personalisation: For students with disabilities or special learning requirements, VR simulations can be adjusted to accommodate their unique needs, providing a more inclusive learning experience.

Multi-sensory engagement: This multi-sensory approach can be particularly beneficial for students with sensory processing disorders or those who require alternative forms of sensory stimulation to enhance learning.

Access to remote learning: VR technology enables remote learning opportunities, allowing students with physical disabilities or mobility impairments to participate in educational activities from anywhere with an internet connection.

Real-world applications: For students with disabilities or special needs, this hands-on learning approach can be invaluable in preparing them for real-life situations and increasing their independence.

VR offers benefits in education for both general and special-needs education students. Immersive learning applications enable students to practice classroom concepts extensively, facilitating deeper engagement with lessons. Teachers can utilise VR to conduct virtual field trips worldwide, enriching lessons with immersive experiences. For instance, a lesson on ancient Rome can be enhanced with a virtual tour of the Colosseum, showcasing the endless possibilities of VR in education.

The virtual reality trip in ancient Rome for a special-needs student affected by ADHD can improve the overall effectiveness of learning in several ways. By leveraging the immersive capabilities of VR technology, students can engage with historical content in a more meaningful and effective way, ultimately enhancing their learning outcomes and fostering a deeper appreciation for ancient history. Also, the immersive nature of VR can captivate students' attention, providing a highly engaging learning experience. By transporting students to ancient Rome, VR can help mitigate distractions and improve focus, which is particularly beneficial for students with ADHD who may struggle with maintaining attention in traditional classroom settings. Additionally, the VR experience enables interactive exploration of historical environments, allowing students to navigate and interact with virtual representations of ancient Roman landmarks, buildings, and artifacts. This hands-on approach encourages active learning and curiosity, as they can investigate different aspects of ancient Rome at their own pace, fostering a deeper connection to the subject matter.

VR apps offer multifaceted lessons tailored for special-needs students, fostering learning across various domains. These apps can teach social, purchasing, safety, and daily life skills, integrating seamlessly into occupational therapy programmes. VR enables students with disabilities to practice real-world skills within a safe virtual environment, mitigating the risks associated with unfamiliar scenarios. For children and adolescents with autism, VR can provide invaluable experiences, allowing them to navigate challenging situations like grocery shopping, using public restrooms, or traveling, all while reducing anxiety. Additionally, virtual field trips offer opportunities to explore inaccessible community locations, enriching students' learning experiences.

Game-based learning

VR is poised to revolutionise the use of games for learning, particularly in special education. Game-based learning is effective due to its ability to enhance engagement and motivation, and VR can elevate these benefits even further. Special education instructors, who have long utilised games and simulations in their lessons, highlight the significant impact of VR games on student engagement. VR levels the playing field, fostering acceptance and eliminating barriers based on gender, weight, or race. Virtual environments offer unique opportunities for learning that are not feasible in real life, and the immersive experiences provided by VR contribute to enhanced learning and retention. Overall, VR has the potential to transform educational experiences for students in special education settings.

2.8. A virtual tour to a university server room

Petra Oberhuemer

In the course "Fundamentals of Information and Communication Technologies" at WU (Vienna University of Economics and Business), students explore a server room via a 360° video. The lecturer of the course is Michael Feurstein.

Problem and target

The aim of the course is to give students a basic understanding of what "the cloud" is all about. They learn that, technically, it consists of rack-mounted computers in a high-security environment, and they become aware of noise levels and disturbances in such an environment. The lecturer explains how technicians can maintain a rack-mounted server in this environment.

Figure 42: Behind the scenes: inside a server room, SEPA 360.
Source: SEPA 360.

The 360° scenario was integrated into a course unit of “Fundamentals of Information and Communication Technologies“ in March 2022. It was used with students of WU, the implementation was in the framework of the project SEPA 360 (Supporting Educator’s Pedagogical Activities with 360 video).

Figure 43: Integration of the 360° scenario in the course unit.
Source: M. Feurstein (WU)

The 360° video is available via the [SEPA360 Video Library].

What benefits it would have for users

Feedback from the students indicated that they perceive the social virtual reality environment to be low-threshold, even without previous experience. Only a few students needed a familiarisation phase/support while participating in the immersive experience.

Students also stated that they can imagine using virtual spaces to enter further environments which would otherwise be inaccessible to them. It was for them a virtual excursion in a playful atmosphere.

Summary

Students were able to visit a server room via a 360° video. The integration of the video in the course unit was like a virtual excursion to a space that usually cannot be visited by student groups. Students perceived the environment as easy to handle, not much support was needed.

2.9. Icebreaking in VR to kick-off international higher education courses

Petra Oberhuemer

Students from four different countries participated in two courses offered by the European University Engaged in Societal Change, of which WU (Vienna University of Economics and Business) is part of. In a social VR environment, students got to know each other through playful icebreaker activities before courses began.

Target/aim

The joint tasks to be completed within the courses were challenging and the students did not know each other beforehand. A carefully crafted social VR environment was used to allow students to be in the same place at the same time and to facilitate authentic communication. The icebreaker activities should encourage students to share information about themselves, their interests, hobbies, or favourite travel destinations. These playful and facilitated activities (e.g., movement activities, matching games, etc.) motivated the students to spend some fun time together and get to know each other. In one of these exercises, the students were invited to come up on the stage if they knew the meaning of a very specific term from one of the partner countries.

Figure 44: Movement activities in social VR environment for icebreaker activities. Source: WU Vienna.

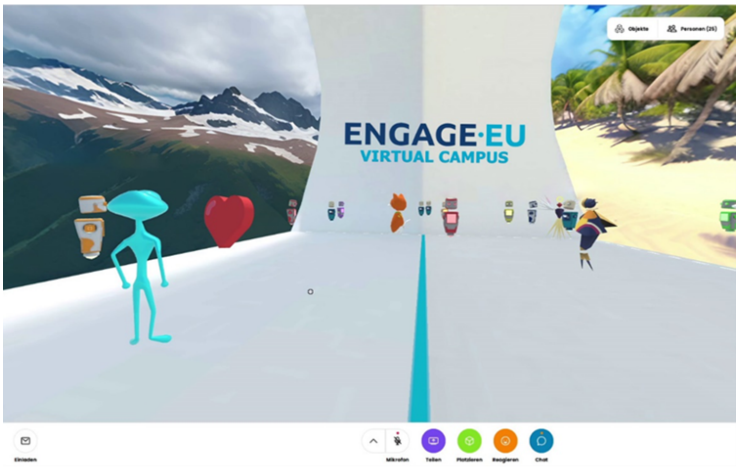

Figure 45: Matching game in social VR environment for icebreaker activities. Source: WU Vienna.

The icebreaker activities in social VR were used in the courses "Future of Work" in which 60 students participated, and "Digital Ethics" in which 30 students participated, in winter term 2023/24.

Benefits

The events were documented using observation and discussion protocols. An online questionnaire was sent out to the students after the events. For most students, this was their first experience of social VR. Almost all of them were able to navigate and act within it. They enjoyed meeting peers and the variety and fun of the activities. The fact that they could try a new technology was seen as motivating. However, some students could not log in to or enter the VR environment. A short live onboarding session should be mandatory instead of sending out guidelines and just offering to enter a VR room for training.

Summary

The students quickly became familiar with the virtual reality environment although most of them had no prior experience using VR. Playful activities in an immersive 3D environment are a good icebreaker. They allow students to get to know each other in an informal way. This is a basis for effective collaboration within the course.

2.10. Augmented and mixed reality and 360° videos in training fire fighters/chemists

Justina Pluktaite

Context and rationale

The increased use of digital media accelerates the integration of technologies such as AR, VR, 360° videos and Internet of Things (IoT). Relevant pedagogical experiences with these technologies, especially in vocational education and training (VET) settings, are rather seldom or non-existent. The gap of relevant practical teaching and learning materials prevents a wider use in VET. This has an impact on the activities of VET teachers in training institutions who are not able to train their learners according to the existing and future needs of the industry. The deterioration of professional competences of learners, such as students and apprentices, can lower the training tendency of companies and decrease the demand of offers in VET schools.

Problem

Live training for firefighters on handling accidents involving electric cars is costly for training centres to organise, as it requires repeatedly sourcing and dismantling new electric cars. It would carry high risks, and it is dangerous to work with electrical batteries. In addition, learning from videos or photos is not putting the learners in the actual situation for decision making, problem solving, situational awareness and understanding. Trainers have big groups to coordinate, and it is challenging to provide learners with traditional learner-centered training.

VR training projects

In the Erasmus+ funded project FightARs seven partner organisations teamed up to work on providing training for firefighters in immersive rescue environments. These organisations were:

- Střední průmyslová škola chemická Pardubice (Czech Republic, coordinator, here after SPSCH Pardubice)
- Sächsische Bildungsgesellschaft für Umweltschutz und Chemieberufe Dresden mbH (Germany, partner)
- Ugniagesiu Gelbetoju Mokykla (Lithuania, partner)
- University of Žilina (Slovakia, partner)
- S.C.P.SERV LIMITED (Cyprus, partner)
- The Estonian Academy of Security Services (Estonia, partner)

In another Erasmus+ funded project, "DIOS - didactic innovation labs –digitalisation experts in VET" five project partners from various sectors teamed up on a similar project. The project partners were:

- Sächsische Bildungsgesellschaft für Umweltschutz und Chemieberufe Dresden mbH (Germany, coordinator)
- Graafschap College (The Netherlands, partner)
- S.C.P.SERV LIMITED (Cyprus, partner)
- Solski Center Kranj (Slovenia, partner)
- SPSCH Pardubice (Czech Republic, partner)

The FightARs project was running from November 2020 to April 2023 and the DIOS project was running from November 2020 to March 2023.

Purpose and use case

Within the FightARs project, the partner organisations tested AR/MR solutions to reduce the above-mentioned challenges and enrich live training of firefighters with immersive technologies (AR/MR glasses and learning management system content).

Within the DIOS project, SPSCH Pardubice was testing AR/MR solutions including IoT technical tools collaboration to enrich chemistry students training.

Project implementation

Within the FightARs project:

- The project partners developed a FightARs app which was enriched with content from the internet to have flexibility for trainer to adjust content without help from the developers.
- They tested an assist possibility where learners were guided remotely through the tasks helping to evaluate the situation of a car accident while having free hands to proceed with actions.
- They tested 360-degree videos to immerse in the firefighters training environment, to train situation understanding, etc.

Within the DIOS project:

- They project partners tested the "guides" tool to increase self-paced individual learning methods. While learners are easily guided through steps (with photos, videos, text instructions), they have free hands to proceed with chemistry experiments.

- Visualised live data through holograms from a chemistry laboratory sensor was providing more understanding of the processes and providing data.
- The project partners tested a 360-degree photo and video tool to offer learners to immerse into a chemistry laboratory environment which has limited access (i.e., age, distance, high risk because of hazardous materials, etc.).

Figure 46: Firefighter wearing AR/MR glasses.
Source: FSPSCH Pardubice 2024.

Figure 47: AR/MR: guiding learner during the training from the distance (1).
Source: SPSCH Pardubice 2024.

Figure 48: AR/MR: guiding learner during the training from the distance (2).
Source: SPSCH Pardubice 2024.

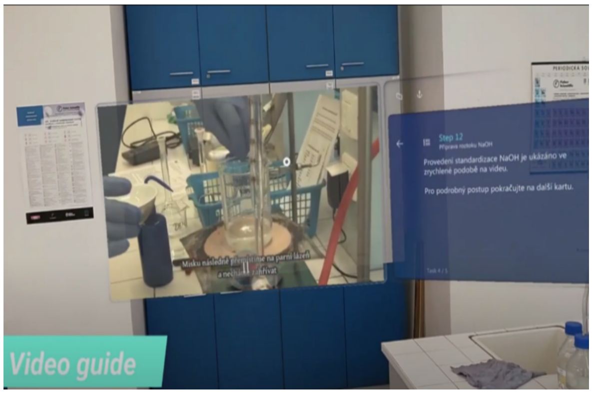

Figure 49: AR in chemistry: guiding learners, individual work.
Source: SPSCH Pardubice 2024.

Benefits

Trainers can have several benefits from using AR/MR in training:

- Reduced risks for learners' health during training
- Reduced costs of organising repetitive/expensive trainings
- Create self-paced individual training with the possibility to carry out practical actions (free hands)
- Support learners in distance training
- Provide opportunity to immerse learners into a limited access environment
- Increase learners' situation awareness and understanding skills in training
- Increase learners' learning motivation
- There are various opportunities to extend the capacity of immersive technology use while connecting with IoT solutions (e.g., connecting with sensors to retrieve data needed)

Challenges and risks

- There are very limited educational AR/MR programmes that are specifically tailored for VET or education in general (aside from medical and private company trainings)
- Technology use is still limited in specific environments (e.g., bright light, humidity, in hazardous locations)
- Using AR/MR glasses can be tiring and there is a time limitation (maximum of 40 min)
- Trainers need to understand the technology before starting to review pedagogical benefits of choosing technology for specific learning outcomes
- AR/MR glasses are expensive. Within both projects, Microsoft HoloLens2 were used. These are currently the only option of AR/MR glasses where one can interact with holograms and digital twins and still see open reality. They cost around 4 200 EUR. After the project, Meta released Quest 2/3 and Apple released VisionPro, both of which have AR/MR capabilities
- Some software solutions are expensive for smaller organisations with smaller training teams
- Programmes are sometimes fixed and limited in terms of flexibility for trainers
- Development of tailor-made educational programmes is expensive and time-consuming

Summary

Two Erasmus+ funded projects, FightARs and DIOS, gave organisations the possibility to train trainers and learners on AR/MR and 360-degree video educational solutions to enrich trainings in VET. These have a great potential, but there is currently a lack of experts who can develop educational material for specific vocational trainings. The current market is focused on gaming and less on education. However, based on the positive feedback in these two projects, this can still be seen as a good step towards the development of more solutions in VET.

2.11. VR as a social place for debating between schools

Leonardo Lorusso

Context

In 2022 INDIRE (Italian National Institute for Documentation, Innovation and Educational Research) conducted a pilot experiment focused on the practice of debate in a VR environment. The pilot involved teachers and students from ten Italian upper secondary schools.

The initiative was driven by the search for new approaches to distance learning since the Covid years had shown how distance can be a limiting factor for schools, teachers and students. What was missing, according to many, was precisely the lack of presence, of "being there" together with other people, sharing the same place as a social (as well as a learning) environment.

This was the question behind the research: Is it possible to recreate the dynamics and feelings of "being physically there" in a distance learning environment? If so, to what extent? And what differences are there compared to physical presence?

With the pandemic behind, the problem of forced distance for schools no longer existed but, through VR, the concept of feeling in the same place between physically distant people could still be applied to a variety of contexts, such as the possibility of connecting students from geographically distant places. For example, students from two or more different schools (or from home) could have a feeling of being present in the same environment.

To this end, INDIRE decided to develop a VR application and test it with teachers and students from different and geographically distant schools engaged in learning activities. The application was developed specifically for this purpose, in cooperation with the Italian company H-Farm, and it was based on the use of Meta Quest VR headsets, being the most widespread and among the most affordable hardware for VR, and already available in many schools.

In deciding what type of learning activity the virtual environment should support, the choice fell on debate for several reasons:

- Debate is a very common learning activity in Italian schools, so it would have been easy to find schools that were already familiar with it;
- Debate has well-defined roles and rules, unlike other, much less standardised practices. This would have made it easier to share the same practice between different schools;

- Debate has to do with communication between people, not only verbal but also non-verbal communication, and it would have been interesting to see how both would be conveyed in a virtual environment.

The virtual environment

The virtual environment developed for the experiment reproduces the setting of a debate challenge: There are the corners of the two teams white and blue, three students per team), the podium from which the speaker engaged in the round speaks, and the jury console. Behind the jury there is an audience available for other classmates or guests from other schools.

The participants' avatars speak with their user's voice (moving their lips accordingly) as well as conveying head and hand movements but are not able to convey the user's facial expressions. In other words, the avatar is able to partly convey non-verbal and para-verbal communication, that is limited in some of its components.

One of the judges is also entrusted with the role of "master" of the meeting. Via a dedicated panel, the master brings the various speakers to the podium and enables the judges to vote with respect to the three dimensions considered: content, style, and strategy. The final score is automatically calculated by the system in a summary sheet.

The VR debate challenges

The VR debate meetings were held from October to December 2022.

Ten schools were selected to participate, on the basis of a convenience sampling, considering two basic requirements: to have experience of the debate methodology for at least one year and to have at least four Meta Quest viewers available (three for the students and one for the teacher).

The total number of students involved were 220, of whom 96 participated directly in the meetings as debaters, equally divided between males and females. The ten classes ranged from grade two to grade four. The first and fifth classes were excluded from the challenges in order not to have excessive disparity in the level of the debate meetings between the different classes.

Each of the ten schools involved participated in one challenge per week with another school for a total of four weeks. In order for the whole class - and not only the students directly involved in the challenges - to participate, debate challenges were cast on the interactive whiteboard or other screen in the classroom, so that even classmates not equipped with headsets could watch them. Sometimes the students involved in the debate were in the classroom together with their classmates, or they used a different room specifically dedicated to the pilot activity.

With regard to the format chosen for the debate in VR, it was decided to adopt the World Schools Debate in a simplified and shortened version (speeches were reduced from eight to three minutes) and with some modifications (absence of point of information) to ensure that the meetings did not exceed a total duration of 30 minutes, which is considered the recommended maximum time, without interruptions, of exposure to the viewers. The criteria for the evaluation of the challenges were borrowed from the National Debate Championship (retaining the dimensions on content, style and strategy) and entrusted to juries of two or three people (teachers and/or researchers), connected virtually via VR headsets.

Outcomes

Of the 20 VR debates planned in the pilot, 19 were completed. This can be considered a first, generic indicator of the concrete feasibility at school level of this kind of activity.

The answers to the questionnaire administered to the students also show that 40.3% of the respondents rated the experience very satisfactory, 27.4% extremely satisfactory, 25.8% fairly satisfactory, 4.8% not very satisfactory and 1.6% not at all satisfactory.

The findings from the focus groups with students and interviews with teachers show that time spent in VR feels more dense and concentrated.

However, feedback from the interviews and focus groups with the teachers revealed that managing these activities was still a lot of work for some schools, both from a technical and a logistical/organisational point of view.

From the **technical point of view**, in several cases hotspot connections via mobile networks had to be used because the security settings of the schools' network firewalls prevented connection to and from the VR application. This would have required the schools' technicians to reconfigure the firewall which, in some cases, was successfully completed, while in others it was not possible. In addition to connection problems, the headsets management often implied the constant presence of a technician in the classroom, both to the setting stage and to deal with ongoing problems. One teacher commented: "Virtual debating forces us to have technical figures to support us, you cannot improvise: you need to have a lot of skills, not just pedagogical skills. We will probably become more familiar with these tools over time, but for now it is not easy to manage."

From a **psychological point of view**, one of the most appreciated elements by the students was the comfort that the avatar mediation guaranteed. In fact, one of the most challenging aspects in debating is precisely that of public speaking, which is scarcely practiced in Italian schools and, perhaps for this reason, more difficult to manage. In this regard, one student states: "The anxiety is there but it is better hidden. It made me feel safer not being seen." Considering the specific developmental stage of teenagers, one of the fears most present in adolescents is of being judged by others. Indeed, in the 12-18 age group, teens experience what is referred to as "adolescent egocentrism": The young person perceives a great preoccupation with himself/herself, comparable to being on a permanent social stage. He/she tends to exaggerate the attention and interest that others would give him/her and this tends to generate a consistent insecurity about being under social scrutiny, moreover, with an audience that he/she does not perceive as indulgent. Therefore, the fact of using an avatar that shields from exposure to judgement is perceived by many as an advantage.

From a **cognitive point of view**, an interesting potential was found, namely the elimination of sources of distraction. The students reported that the virtual environment helped them to concentrate better because, compared to the classroom environment, it was tailor-made for the debate: no distracting elements (objects, furniture, people, noise) but only what is required for the activity. What is not needed is left out in the real world. On the other hand, the risk of dissociation or loss of a sense of reality in VR did not emerge in this pilot; on the contrary, most of the students spoke of a surprising sense of realism.

In terms of motivation, the teachers emphasised that strengths included greater involvement in the preparation of the debate, greater attractiveness of the experience (also towards the content covered) and the use of language that was semiotically closer to the students. Student engagement, therefore, would be guaranteed.

Conclusions

The pilot showed how the use of VR in the classroom - if accompanied by the design of a context of use compatible with the schools' objectives, times and spaces - can already be a concrete and applicable possibility. Moreover, the potential of VR in enabling new forms of interaction between students from different schools emerges, providing them with a co-presence space in which to communicate and act together. On the other hand, it is pointed out that current generation of VR headsets need further ergonomic improvements to overcome the physical discomfort that some students complain about. And there is confirmation of how the introduction of a new technology or a new media at school always requires a phase of adaptation of logistical/organisational practices and the development of new professional skills, as already seen in the past with the advent of computers, the internet and interactive whiteboards.

With regards to the psychological aspects related to the learning experience, several elements emerged that will have to be further investigated in the future. Indeed, it seems from the students' considerations that debate in VR can help reduce anxiety and shame in exposing oneself to the judgement of others, in public speaking, representing, especially for teenagers, a sort of safe zone, a practice environment in preparation for reality.

The pilot also suggests exploring in further detail some research directions that emerged during the activities, such as the application of mutable engagement elements from video games (e.g., a ranking system between students/teams participating in the meetings) and the psychological effects on students of an avatar-mediated corporeity.

2.12. Future-oriented good practice in immersive learning

Rossana Latronico

The following example is in the context of the Italian National Digital School Plan (PNSD) with best practice and future recommendations relevant to educators.

The PNSD has provided fundamental endowment of infrastructure and equipment to all schools and set paths aimed at enhancing the digital skills of students, pupils, teachers, managers and administrative staff. At the same time, the pandemic period revealed the significant opportunities that digital education offers and the need for a systemic integration between the use of hardware and software, skills and work and teaching methods.

Trends in digital transformation

The document highlights the evolution and strategic objectives of the PNSD, emphasising a significant trend in the educational sector: the integration of digital tools and methodologies to enhance teaching and learning experiences. The trend underscores the necessity for a systemic approach, blending design and implementation of digital innovations to make education more accessible, inclusive, and effective.

Use case and good practice

One notable good practice exemplified in the document is the educational project titled "Un Mito Ci Vuole". This initiative involves students from different schools who explore myths through digital storytelling in a custom-created eduverse (educational metaverse). The project integrates humanities and technology, fostering collaboration, critical thinking, and digital literacy among students.

Benefits of the trends

The benefits of these digital transformation trends in education include:

- Enhanced educational access and inclusion: Digital tools help bridge educational gaps and cater to diverse learning needs.
- Skill development: Students and educators enhance their digital literacy, preparing them for modern challenges.
- Innovative teaching methodologies: The use of digital platforms like eduverses encourages active and participatory learning.

Current research and practices

The document references ongoing research and practices under the PNSD, which aligns with broader European initiatives like the Digital Education Action Plan (2021-2027). This research is focused on understanding the current digital capabilities of schools to better tailor future innovations.

Scope for embedding into the curriculum

The trends and practices discussed are directly applicable across various educational settings, including higher education institutions, VET, schools, and adult education programmes. The PNSD's focus on integrating digital methodologies into ordinary school activities and curricula promotes a widespread and systematic adoption of these innovations.

2.13. Summary

Jackie Toal

This chapter has aimed to provide an insight and overview of best practices used within educational institutions in Europe in digital education. These have been presented to help inspire, share experiences and illustrate real world examples. These examples show how immersive learning can boost student engagement, promote social learning, simulation training for industry, promote empathy in learning, stimulate critical thinking via virtual debates, learn about culture and history as well as promote language learning.

The next chapter will explore and provide insight into emerging trends and recommendations for the future.

References

Abatte, E. (2023): Exploring students' perspectives on immersive STEM laboratory learning: A case study of ECVAM 3D Lab and Futuclass, https://school-education.ec.europa.eu/en/insights/research/students-perspectives-immersive-stem-laboratory (accessed 10 May 2024).

Bachiller, C., Monzo, J. M., & Rey, B. (2023): Augmented and Virtual Reality to Enhance the Didactical Experience of Technological Heritage Museums, Applied Sciences, 13(6), 3539, https://doi.org/10.3390/app13063539.

DIOS partnership (2021): Didactic guides. How to qualify educational personnel to become digitalisation experts in VET, https://dioslab.sbg-dresden.de/en/images/Guidelines/IO1_Didactic_guidelines_EN.pdf (accessed 03 May 2024).

DIOS partnership YouTube channel (n.d.): https://www.youtube.com/@dioslabs4134/videos (accessed 03 May 2024).

Donnelly-Hermosillo, D. F. (2023): Undergraduate Student Learning and Perceptions of a Virtual Reality Chemistry Activity, https://alisxr.com/wp-content/uploads/2023/06/ALIS-XR-2023-Presentation-Dermot-Donnelly-Hermosillo.pdf (accessed 10 May 2024).

ENGAGE.EU (2023): Signature Course "The Future of Work", https://www.wu.ac.at/en/engageeu-signaturecourse (accessed 03 May 2024).

FightARs partnership (2021): Pedagogical guidelines, http://fight-ar.com/wp-content/uploads/2023/07/FIGHTARs_PEDAGOGICAL-GUIDELINES_EN-1.pdf (accessed 03 May 2024).

FightARs partnership (2023): Best Practice Guide, http://fight-ar.com/wp-content/uploads/2023/08/FightARs-BEST-PRACTICE-GUIDE_FINAL.pdf (accessed 03 May 2024).

FightARs partnership YouTube channels (n.d.): https://www.youtube.com/@fightars8035/videos and https://www.youtube.com/@fightars7654/videos (accessed 03 May 2024).

Mulders, M. (2023): Learning about Victims of Holocaust in Virtual Reality: The Main, Mediating and Moderating Effects of Technology, Instructional Method, Flow, Presence, and Prior Knowledge, Multimodal Technologies and Interaction, 7(3), 28, https://doi.org/10.3390/mti7030028.

Polikarpus, S., Hofmann, J. (2022): Application of Augmented Reality in firefighters training: From Safe to SafAR, GI VR / AR Workshop 2022.

Kopúnek, J., Štefko, T. (2023): Immersive Education of University students using Augmented, Virtual and Mixed Reality, in DOKBAT 2023, 19th International Bata Conference for Ph.D. Students and Young Researchers (Vol. 19), Zlín, http://dokbat.utb.cz/conferenceproceedings/ (accessed 03 May 2024).

Stiefelbauer, C., Ghoneim, A., Oberhuemer, P., Vettori, O. (2023): Verschränkte Lernwelten: physisch, virtuell, seamless, Zeitschrift für Hochschulentwicklung, 18 (Sonderheft Hochschullehre), p. 159–179, https://doi.org/10.3217/zfhe-SH-HL/09

.

Stiefelbauer, C., Janko, M. (2023): Innovating Teaching and Learning with Immersive Technologies at WU Vienna, in Bastiaens, T. (ed.), Proceedings of EdMedia + Innovate Learning, Vienna, p. 1051-1054.

PART 3

Emerging trends, opportunities, challenges and recommendations

3. Emerging trends, opportunities, challenges and recommendations

Jackie Toal

Digital education is continuously evolving with the emergence of new tools, technologies and methods of delivery including online, blended and face to face. In this chapter, the aim is to explore the developing trends in immersive learning, such as integration of AI and related opportunities, uses for creative education, learner engagement, creating immersive environments with more realistic avatars and social presence, as well as digital twins as immersive environments. Examples are provided in the context of current research.

The following are some key trends that provide potential opportunities for digital transformation, with some examples of use cases, current research into practice and scope for embedding into the curriculum.

3.1. Trend: integration of AI in VR tools

Cristina Obae

With its ability to generate realistic and immersive experiences, power virtual assistants, and assist users with information retrieval, AI is poised to play a crucial role in the metaverse. At the time of writing, it seems that OpenAI, Google, and Microsoft are at the forefront of this development, with ChatGPT, Gemini, and Copilot contesting for dominance in the search and content creation space.

There are multiple companies looking at ways of embedding AI tools or AI-generated objects in VR spaces. For example, WondaVR, FrameVR and Engage are proposing AI-powered non player characters (NPCs) and generation of 3D objects or even 3D environments through prompts. From a technological point of view, it is just a matter of integrating the different generative AI tools into the different software development kits. The impact on education, however, could be very important.

Use cases

Harvard University imagined a murder mystery exercise in which French beginner students created their own VR avatar, where 'each student placed their compositions and written work from in-class activities including their self-portraits, alibis and questions regarding the murder mystery in a prompt for their AI character using a simple copy-paste' (Wonda), then interrogated all suspect characters looking for the guilty one. Engagement and motivation were the main benefits that encouraged the integration of such activities into the curriculum. ‘Overall, the project integrated attention to grammatical accuracy, comprehension of both written and audio texts, and writing skills in a simulated, yet culturally grounded, context’ (Wonda).

Another interesting use case is the School of AI where students can engage with AI-powered NPCs taking the visual appearance of notable historical figures like Marie Curie, Albert Einstein, Nikola Tesla, Benjamin Franklin, Neil Armstrong, etc.

The benefit is important in terms of understanding of the personality, historical context and engagement. Interacting with “living” avatars can bring extra motivation to students to dive deeper into different domains and why not make learning more memorable supporting knowledge retention.

A third use case is AI to generate 3D spaces or 3D objects such as it is the case in FrameVR. Luna AI for example is a robot that students can interrogate in writing for learning about different topics such as conjugation of verbs in French or different cultural events. Then they can write the script to use AI to generate a new environment or objects to illustrate their discoveries. AI-generated close-captions (CC) are also an important usage in foreign language classes as the teacher can use only the target language and students have CC on for a more detailed understanding.

Embedding AI and VR into curricula has benefits in terms of motivation, learning outcomes and engagement. If used in a reflective way and aligned with the learning goals, such technologies have great potential to improve educational experiences and take learning to new dimensions.

3.2. Trend: AI on XR and immersive learning for creative uses in metaverse

Jackie Toal

Potential of AI and XR for digital transformation

The “metaverse” offers opportunities for new ways to engage learning particularly in online distance education as the next iteration for both 3D virtual collaboration combined physical and digital via social real time interactions (Phakamach et al. 2022). With generative AI, this has the potential to have a significant impact for digital transformation on Immersive learning under the realm of XR, offering personalised learning experiences, adaptive storytelling, intelligent tutoring systems, enhancing creativity, critical inquiry, performance analysis and feedback as well as automated content generation (Hughes 2023). Additionally, there are opportunities for improving accessibility and inclusion (Rangel-de Lázaro, Duart 2023; Nicholson 2024).

Use cases for AI with XR

Generative AI can be used for immersive animation, creation of immersive art and learning. The use of empathetic avatars, dynamic storytelling, holographic projections and interactive simulations combining a fusion of AI and XR Immersive technologies can provide opportunities for new ways for immersive learning.

Trends include more real-time content creation for motion capture and body tracking. Figures 50 and 51, use AI for SayMotion, in which a short written description can generate a movement of choice (e.g., walking, cycling, running), as well as allowing for the use of videos and movement of a human to be transferred to a 3D character.

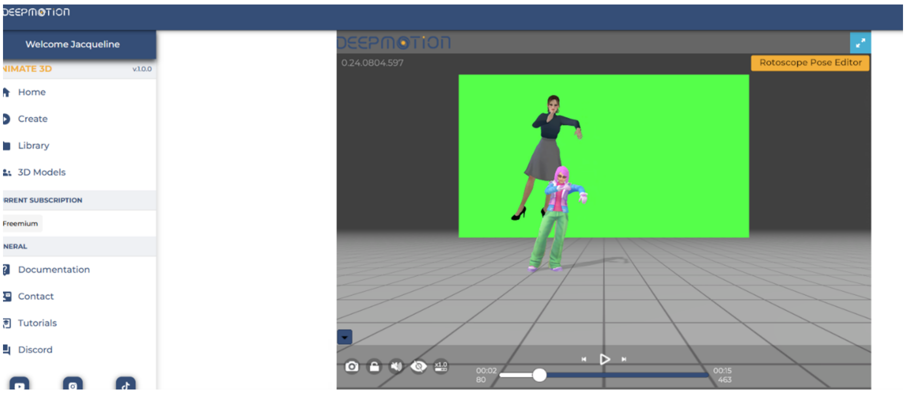

Figure 50: Deep motion graphic from website, illustrating process.
Source: By Jackie Toal created with free user licence software.

Figure 51: Animate with 3D: example of free green screen video mapped onto 3D model.
Source: By Jackie Toal created with free user licence software.

A similar alternative is Masterpiece X, as to be seen in figures 52 and 53.

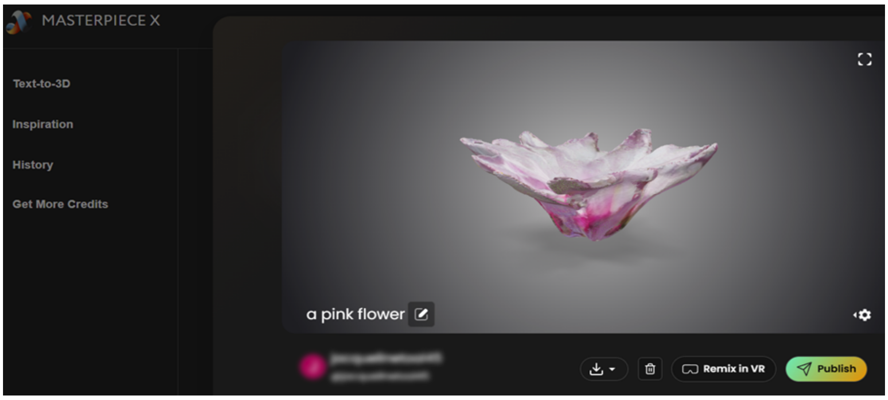

Figure 52: Masterpiece X generative AI prototyping.
Source: Generated in Deep Motion by Jackie Toal, created with free User Licence by Masterpiece X.

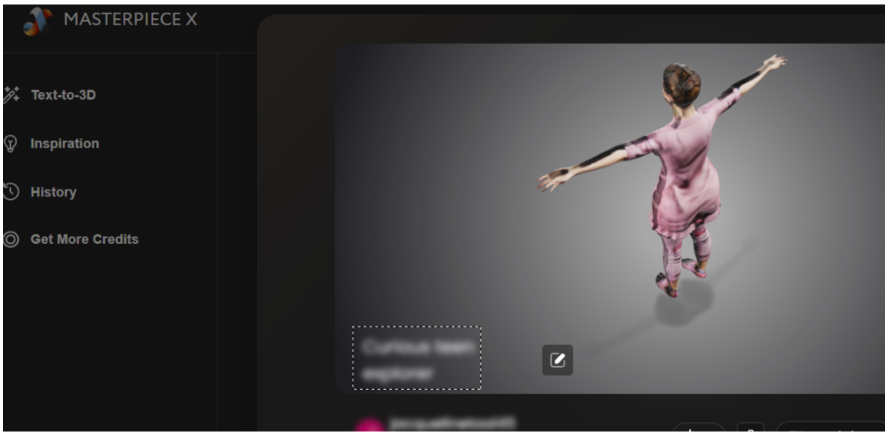

Figure 53: Masterpiece X 3D creation tool in VR, Masterpiece X, 2024.
Source: Generated in Deep Motion by Jackie Toal, created with free User Licence by Masterpiece X.

The potential of these tools can add value and enhance the productivity of designing for animated immersive learning experiences. Similarly, Pose AI (figure 54), captures motions and can examine the data in real time, which could similarly have an enhanced effect in immersive learning.

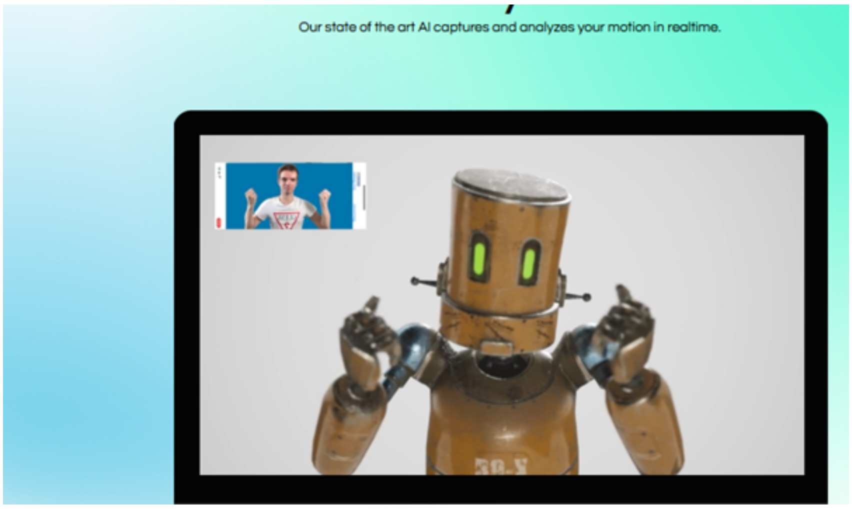

Figure 54: Pose AI for motion capture for 3D avatars.
Source: Pose AI 2024.

Empathic avatars created with AI is the focus of the research by Hume AI using more meaningful voices with avatars that reflect emotion, using a combination of speech, dynamic reaction and facial expression. When incorporated with XR, this offers potential for more meaningful learning experiences. Sinai (2024) also suggest AI can have an impact on characters for AR with use of AI algorithms for behaviour. CoSpaces Edu also offers opportunities for the use of AI enabled voice integration. Sora AI, offers digital transformation potential with AI generated videos.

Benefits: These tools can speed up the workflow, add value, allow for more ideation with a 3D space. AI can allow for the creation with immersive technologies for more engaging content and is important for more personalised experiences, generating more realistic content (Sinai 2024).

Current research and into practice

An exploration of new AI enabled prototyping and "Explainable AI for XR" with generative AI for multimedia uses, animation and 3D spatial and tangible interactions was a focus of Suzuki et al. (2023). Nisiotis and Lyuba Alboul (2021) have researched XR, AI and robotic technology to support immersive learning using a combination of "Fetch" robot and digital twinning. This research investigates robotics with XR, AI to support immersive learning and explores intelligent interactive experiences to support learning.

Recommendations and scope for embedding into the curriculum

All these tools can be embedded into design of creative immersive experiences. They can be used for arts education, games, animation and more, and also for design of learning experiences. These tools encourage responsible discussions, usage and effective prompt engineering with AI into XR (Hughes 2024).

Challenges and concerns with AI in VR

Costs of headsets for VR production have been reduced, but setting up accounts and entering data can still be challenging. Qayyum et al. (2023) highlight security concerns of data with AI and XR. Legal and ethical considerations include copyright concerns, bias, issues of representation, privacy and "hallucinations" with AI (Hughes 2023), so these are important considerations for usage of AI responsibly.

Challenges and considerations of immersive technologies for immersive learning

Immersive learning can be highly innovative and supportive for cognition, emotional development, development of deep learning and higher order skills. However, there are challenges that educators need to be mindful of and pay attention to:

1. **The prohibitive costs:** Headsets have reduced in cost over the past number of years, and there is continuous improvement and development of this technology. Development and designing with VR and AR can be expensive. Integration within an education establishment may also involve working closely with IT departments to ensure software are regularly updated to ensure a smooth learning experience. Software updates and maintenance are important to reduce any hardware or software bugs.
2. **Accessibility of the technology:** Depending on curriculum delivery, not all learners and educational establishments may be able to afford or have access to these technologies. Therefore, they pose a potential risk of increasing the digital divide.
3. **Health considerations:** A prolonged period of using a VR headset can lead to motion sickness or VR sickness resulting in headaches, dizziness, or eye strain, resulting in impacts on the learning experience. Limits on usage need to be set. Risk assessments as well as health and safety considerations are important. Each educational establishment must investigate to meet their own learner needs and to implement recommendations.
4. **Content limitations:** Learning content for immersive learning is limited in comparison to learning content with a traditional desktop. For an educator who wishes to create or adapt content to VR, this experience can be time consuming.
5. **Privacy, data protection and security:** Many of the applications require users to log in and enter user details. There is a large amount of data which can be sensitive to which can be collected including performance and biometric data. Ensuing privacy and security is essential.

6. **Equity and inclusion:** In the educational realm, ensuring that immersive experiences and tools are accessible to all students including those of neuro-diversity, disability, learning needs and geographically dispersed is a challenge (Serrano-Ausejo, Mårell-Olsson 2023).

To address these challenges, it is important that educators are trained in the use of the immersive learning technologies including staff training initiatives both in educational establishments as well as other organisational bodies. Health and safety within one's own institution should be considered, and complete risk assessments and relevant documentation need to be in place. One also needs to develop secure and robust technical support with IT to handle any hardware and software issues - constant maintenance is essential here. Learning materials that are accessible and inclusive need to be designed, and collaborative initiatives for learning and content creation are encouraged.

3.3. Trend: AI integration into immersive learning for digital and soft skills

Salvatore Mica

The rise of AI-based automation is poised to impact up to two-thirds of existing jobs in the near future, necessitating significant adjustments in education and vocational training. The consequent rapid transformations in the labour market render the traditional notion of skills inadequate, both within educational frameworks and in the context of employment. This prompts a critical examination of whether a more expansive comprehension of competencies is imperative for curriculum development. The emergence of generative AI will refine digital skills, thereby compelling policymakers to reassess the very definition of digital proficiencies.

Current research

On the futures of technology in education: Emerging trends and policy implications (Tuomi et al. 2023).

Also, the overgrowing diffusion of AR, VR, and XR applications, tools, and environments adds many skills to the curriculum. That skill set should be studied and taught to the teachers, but also to the students.

Another important skill area in rapid change is transversal skills and human-centred competencies, such as creativity, problem-solving, and socio-emotional aptitudes, which arise from the interplay of individual and contextual factors and remain resistant to easy substitution by technology. As Abdelouahab (2020) mentioned, AI systems could serve as indispensable assistive tools, facilitating a shift in educational focus towards nurturing skills that have traditionally been sidelined from formal curricula.

Extended reality vocational training's ability to improve soft skills development and increase equity in the workforce (Boland 2023).

This raises the question of whether a recalibration of digital skills is warranted, particularly in light of the ambitious targets outlined by initiatives like the Digital Compass (European Commission 2021a) and the European Pillar of Social Rights Action Plan (European Commission 2021b). These targets aim to ensure that 80% of adults possess basic digital skills and to employ 20 million Information and Communication Technology (ICT) specialists within the EU, with a specific emphasis on fostering greater participation by women.

Benefit

VR and AR applications are best suited for the purpose of teaching and assessing the so-called "soft skills". Using these environments in addition to AI will provide the training students, workers and teachers need to manage these rapid societal changes.

An interesting use case (Watts 2020) explains how soft skills training could be dramatically improved by the use of VR, XR devices and XR training in practice for adult learning in a professional and working environment.

3.4. Trend: using AI and learning analytics to design assessments in XR

Salvatore Mica

Assessment methodologies wield significant influence over the landscape of education and learning. With the advent of AI, learning analytics and XR tools and environments, there exists the potential for novel, authentic, and continuous assessment practices to emerge.

However, the realisation of these formative assessment methods hinges greatly on the existing regulatory frameworks and the adequacy of ICT infrastructure. It is imperative that regulations, both existing and proposed, are conducive to fostering the development and implementation of these innovative assessment approaches. Additionally, the availability and robustness of ICT infrastructures will play an important role in ensuring the effectiveness and widespread adoption of these new assessment methodologies.

A forward-looking five-year vision for assessment, as delineated by the UK digital technology and education agency Jisc (2020), advocates for a transformation towards greater authenticity, accessibility, inclusivity, appropriate automation, continuity, and security in assessment practices. There are many issues about the assessment and many academic studies analyse the biases and problem the teachers, the evaluators and the designers faced when they needed to design a specific assessment for a specific reason, as Swiecki et al. (2022) show.

Authentic assessment entails measuring practical skills in realistic contexts, such as through immersive simulations tailored to specific subject matter, rather than relying solely on traditional pen-and-paper methods. Likewise, project-based assessment can evolve beyond conventional tests and essays, evaluating project outcomes instead. For example, concerning adult learning and assessment, it is very interesting what Walmart built and delivered to hundreds of thousands of workers and managers. They decided to use a VR application to assess the workers, as Tuchscherer (2019) explained.

Keeping the attention on adult learning and assessment, the Pädagogische Hochschule Zurich (2023) declares:

> *We see virtual reality solutions as a valuable addition to basic vocational education and training. The results of the project indicate that educational-based virtual experiences and learning spaces can support vocational training and be effective in building professional skills.*

Jisc (2020) underscores the importance of appropriately automated assessment, which preserves essential aspects of student-teacher interaction while alleviating teachers' marking burdens and enhancing student feedback. By utilising AI and learning analytics, personalised learning assistants could continuously evaluate student progress and support formative development, potentially rendering certain 'stop-and-test' assessment points obsolete.

Current research and practice

A recent critical review of AI-supported assessment approaches, as outlined by Swiecki et al. (2022), presents various ways through which AI could revolutionise assessment practices:

1. Automation in assessment construction, peer assessment, and writing analytics could alleviate the burdens associated with assessment.
2. AI enables a shift from discrete 'stop-and-test' assessments to continuous formative assessment.
3. Adaptive assessment tasks personalised to students' abilities are made feasible through AI techniques.

4. AI facilitates the creation of authentic assessment scenarios, such as simulations, while also aiding in the collection and analysis of data from complex assessments.
5. Recognising the increasing integration of AI in students' lives and work tasks, new assessment practices must incorporate AI tools into their designs.

Use cases

The following sources are two examples of current use cases:

- Rebekah, T. (2019): Walmart uses virtual reality to test new store managers, https://eu.usatoday.com/story/tech/2019/07/08/walmart-uses-virtual-reality-hire-new-managers/1635311001/ (accessed 10 May 2024).
- Pädagogische Hochschule Zurich. (2023): Virtual reality improves apprenticeships, Digitalisation Initiative, https://phzh.ch/en/about-phzh/news-events-and-current-topics/news/2023/virtual-reality-improves-apprenticeships/ (accessed 10 May 2024).

Benefits

These emerging technologies hold the promise of diminishing the emphasis placed on summative assessment and the often-criticised practice of "teaching for the test." Instead, digitally mediated formative and ongoing assessment strategies could gain prominence.

3.5. Trend: holographic presence and immersive simulations

Salvatore Mica

In envisioning the Next Internet (Web 4.0 and Web 5.0), the convergence of physical and digital realms will deepen in complexity and significance. Beyond merely leveraging new technical capabilities like holographic presence and immersive simulations, the fusion of digital and physical domains heralds the emergence of a novel infrastructure for knowledge acquisition and action. This integration with the material environment holds important implications, resonating with several influential learning theories that underscore the crucial role of interaction with the physical world. In that direction, there are many projects and products involving spaces and people, actions and IoT, as discussed earlier.

To grasp the distinction between 6G and preceding communication technologies, it is essential to recognise the foundational importance of spatially and temporally organised human-to-human interactions in shaping societal structures and practices. From Durkheim's classic analysis of the transition from mediaeval villages to global commerce networks to contemporary sociological perspectives on spatial structures' role, the interplay between physical and social landscapes has been a central theme. According to Herrington et al. (2014), authentic learning is rooted in the theory of situated cognition alongside pedagogical methods like anchored instruction, which have evolved over the past two decades. It presents an alternative instructional framework grounded in robust principles for crafting and executing complex, lifelike learning challenges. The internet's advent disrupted the industrial age organisation of time and space, laying the groundwork for a new social infrastructure delineated by Castells (2007). While faster 5G networks solidify this infrastructure, 6G represents a paradigm shift by directly intertwining cognition, space, and action, marking a departure from Castells' network-centric focus.

In learning theories, according to Chatterjee and Hannan (2016), this nexus of cognition, space, and action is particularly evident in constructivist frameworks that emphasise practical experience as a catalyst for learning. Scholars like Dewey and Vygotsky (Glassman 2001) argued that learning is rooted in concrete experiences and practical engagement with the material world. From Vygotskian perspectives on tool-mediated action to Bamberger and Schön's (1983) analysis of learning processes, the interaction between the material and cognitive realms serves as the cornerstone of learning theories.

Benefits

As we transition towards the Next Internet, where human action and interaction are mediated by a real-time digital layer, pedagogical approaches such as situated learning and problem-based learning gain prominence, emphasising the creation of learning environments that mirror real-world contexts. The advent of 6G networks heralds a deeper reorganisation at the level of human cognition and action, with implications for theories of learning and pedagogical practices. The "sensorisation" of the network accentuates the importance of spatiality and embodiment, prompting exploration of extended, embodied, situated, and distributed cognition and offering new insights for educational theory and practice.

3.6. Trend: computer-based adaptive learning environments

Salvatore Mica

Numerous prognoses regarding the future of digital education are predicated on the notion that instruction can be customised and tailored to suit individual students through computer-based adaptive learning environments. Such a vision of personalised instruction delineates clear design imperatives for intelligent tutoring systems. These systems must possess a model of the knowledge domain, an analogous model of the student's knowledge state, a pedagogical model geared towards guiding the student to mastery, learning content conducive to student progress, and user interfaces facilitating seamless interaction with the student (Luckin et al. 2016).

For each constituent component of such systems, it becomes pertinent to inquire whether anticipated technological advancements could precipitate breakthroughs capable of realising the proposed vision. Indeed, certain technology experts have postulated that personalised intelligent tutoring systems are on the cusp of revolutionising education (e.g., Lee and Qiufan 2021).

Benefits

Personalised learning tailors education to individual needs, fostering engagement and intrinsic motivation. It offers flexibility in adapting content and pacing to student progress, promoting deeper understanding. By addressing diverse learning needs, it ensures equitable access to education. Students learn at their own pace, pursuing topics of interest and accessing resources conveniently. Mastery-based progression ensures thorough understanding before advancing. This approach, integrating adaptive technology, enhances learning outcomes by accommodating various learning styles and abilities. Ultimately, personalised learning creates more engaging, effective, and equitable educational experiences, catering to the unique needs of each learner.

Use case

The following source is an example of how generative AI can be utilised for personalised learning in practice:

- Dunajko, M. (2023): Personalized learning: How generative AI is revolutionizing education, Neurosys, https://neurosys.com/blog/personalized-learning-how-generative-ai-is-revolutionizing-education (accessed 29 October 2024).

3.7. Trend: digital twins for immersive learning

Salvatore Mica

Eriksson et al. (2022) highlight that digital twins can revolutionise education by offering immersive, interactive, and personalised learning experiences. By creating virtual replicas of real-world objects, environments, or processes, digital twins allow students to explore, experiment, and learn in a safe and dynamic virtual space. This technology enables hands-on learning opportunities that might be otherwise inaccessible due to logistical constraints or safety concerns. Digital twins, especially within immersive reality environments, offer several benefits in education. First of all, experiential learning: Digital twins provide students with immersive, hands-on experiences that simulate real-world scenarios. This experiential learning approach enhances comprehension and retention by allowing students to interact with complex concepts in a dynamic environment. They provide a visual and spatial understanding of the topic: The immersive reality technology enables students to visualise and explore concepts in three dimensions, improving their spatial awareness and understanding of abstract ideas. This visual and spatial learning enhances their ability to grasp intricate concepts, especially in subjects like mathematics, engineering, and the sciences. The digital twins can also be designed to build and deliver a kind of personalised learning. Digital twins can be customised to suit individual learning styles and preferences. Students can engage with the content at their own pace, explore different aspects of a concept, and receive personalised feedback based on their interactions. This tailored approach promotes deeper understanding and caters to diverse learning needs. And obviously, the digital twin's environment enables a kind of risk-free experimentation and learning. In fields where conducting real-world experiments is costly, dangerous, or impractical, digital twins offer a safe and risk-free alternative. Students can conduct virtual experiments, make mistakes, and learn from them without any real-world consequences. This promotes experimentation and innovation while minimising potential risks.

Benefits

Digital twins in education offer immersive, interactive, and personalised learning experiences. They provide hands-on learning opportunities in safe virtual environments, overcoming logistical and safety barriers. By adapting content to individual needs, digital twins enhance engagement and facilitate deeper understanding. Educators gain valuable insights from data analytics, enabling personalised instruction and tracking student progress effectively. Overall, digital twins make learning more engaging, dynamic, and tailored to individual students, fostering better learning outcomes.

3.8. Trend: Avatars for immersive learning

Salvatore Mica

In future virtual worlds, user interactions and transactions will generate diverse data types, distinct from current digital platforms. Avatars, representing users, will yield data on behaviour, preferences, and interactions, offering insights into emotional states. This first-hand avatar data presents valuable information for enhancing user experiences. Social data analytics, common on current digital platforms, could extend to include avatar-generated data. Next-gen virtual worlds will also produce new spatial and spatio-temporal data, encompassing environment layouts, avatar movements, and spatial computing elements. The evolution of virtual content will most likely be influenced by advancements in AR, VR, XR, AI, and blockchain technologies.

Benefits

This new type of data will be useful for designing and building more tailored on-the-fly learning experiences and a self-paced environment, organised and managed according to priorities, preferences identified by the data, and better knowledge of the users involved.

Current research and into practice

Huda et al. (2018) explore Modern Learning Environments (MLE) in the big data era, emphasising student engagement with online resources via digital devices. It aims to design innovative MLEs using big data to enhance online learning in higher education and proposes a model for improving student outcomes in technology-rich environments.

Lin and Lan (2015) analysed language learning in VR environments from 2004 to 2013 across four top journals. It found popular research topics, including interactive communication, behaviours, and task-based instruction, but noted a lack of focus on teacher impact. The use of triangulation and data collection from informal learning procedures increased. The study calls for further research in specific VR-related fields.

Xing et al. (2021) explore the historical and social impact of VR, AR, and MR through a literature review and data research study. It focuses on a case study proposing a bright future for technology in education and compares it with current developments. By analysing 269 citations from 2005 to 2020, the paper discusses industrial trends and potential future directions for VR, AR, and MR.

3.9. Trend: adaptive learning and serious games for immersive language learning

Sofia Guzzon

The integration of immersive learning experiences in education has improved access to learning resources, benefiting language learning (Alshumaimeri 2023; Checa and Bustillo 2020; Tegoan et al. 2021; Yanes and Bououd 2019, inter alia). Another example of an emerging trend are games designed for immersive learning environments (Pinto et al. 2021).

Games and XR are a promising combination that could have great benefits for second language learners (Pinto et al. 2021). Some studies reported how gamification in VR can provide students with contextualised learning experiences since real-life scenarios enhance involvement and cultural knowledge (Pinto et al. 2021). In other words, gaming within the field of XR technology has the potential to boost authenticity, personalisation, and collaborative learning, increasing at the same time students' motivation, concentration, problem-solving skills, and language fluency (Tegoan et al. 2021). More generically, the area of serious games offers a learner-centred approach, by promoting active and critical learning paths where personal needs and preferences are at the forefront of the learning experience (Dyulicheva and Glazieva 2021). In these terms, "adaptivity" in game-based learning systems plays a crucial role: The idea of customising content based on users' learning style, level and characteristics is essential to boosting students' improvement. In immersive learning contexts, this adaptation process becomes possible thanks to the technology itself, which can provide useful data about users' behaviour by tracking eye movements (Dyulicheva and Glazieva 2021).

Challenges for Immersive learning

However, VR games present some limitations. Extended gaming can cause headaches, eye strain, dizziness, and sickness among students (Pinto et al. 2021). Additionally, technical issues such as connection interruption or device instability may arise (Pinto et al. 2021).

Researchers in this field (Pinto et al. 2021) underline the need for further research about gaming with VR technology in second language education. Advancements in this sense could be made by reaching an agreement about the specific terminology to be adopted in the field and by increasing the number of studies that compare different technologies. Understanding which educational choices and strategies will be more appropriate in the future is indeed crucial (Pinto et al. 2021).

3.10. Trend: XR technology complimented with neurotechnology for immersive learning

Justina Pluktaite

XR technology, complemented by neurotechnology, will be the next step in educational and technological development. Advances in headset technology may also include integration with advances in the way users interfere with training programmes. For example, one neurotechnology company is currently developing a system that can translate human brain activity into actions without any physical movement. In this case, the learner could undertake 'full dive' VR training, where there is complete immersion in virtual reality without the need for physical interaction.

Benefits

Full immersion in VR will empower learners to make more realistic decisions in situations in which they encounter.

3.11. Recommendation: equip trainers and educators with specific digital skills to address skills challenges

Justina Pluktaite

There is a need to equip trainers and educators with specific digital skills. They need to understand technologies from a pedagogical perspective in order to collaborate and create educational and training content. Even in the near future, we will see a great lack of new educators (generational shift) who need to be trained at an early stage (pedagogical universities) and embed a life-long learning push (to increase mandatory digital skills development) in their professional development plans in all educational sectors (primary and secondary education, higher education, VET, adult education).

Immersive technologies in vocational education are on the rise. However, there is very limited access to economically sound solutions that are user-friendly for vocational trainers, who are usually less tech-savvy. However, all developers want to make money, which is why more and more licensed programmes are entering the market. Therefore, if trainers have integrated their technological, pedagogical and content knowledge, they will be able to find new solutions for training.

Benefits

Focusing on training the trainers will ensure the resilience of education systems and the faster adaptability of rapidly evolving EdTech in educational institutions.

3.12. Recommendation: integrating XR into VET

Justina Pluktaite

XR integration in various vocational training and education sectors is slowly moving forward with different use cases. As within each coming year Europe will be losing one million of its skilled workers until 2050, there is a great need to reduce the gap between demand and supply. VET training centres will need to respond and prepare specialists for future needs. Training programmes need to be adjusted, made more efficient, focused on learners. Immersive technologies are one of the solutions to support this transition.

Use case

XR training software can give firefighter trainees the ability to learn and practice skills in an immersive, interactive, and risk-free environment. The XR training experience should also be cost- and time-effective, scalable, easily accessible, diverse, customisable, used to improve and record performance, and environmentally friendly (see chapter 2.10.).

3.13. Recommendations for integrating XR and VR into teaching

Leonardo Lorusso

This is a roadmap for educators to integrate XR and VR technologies for a more engaging, personalised, and effective learning environment.

Empowering teachers with XR tools

Ethical assessment with AR: Move beyond traditional exams by creating immersive and anxiety-reducing AR exam environments. Students can interact with calming visuals and user interfaces, fostering honesty without feeling constantly monitored. AR overlays can subtly highlight potential cheating attempts, promoting academic integrity.

The metaverse classroom: Embrace the potential of the metaverse as a shared learning space. VR and AR simulations can transport students to the heart of rainforests, historical events, or virtual labs, facilitating experiential learning. Collaborative platforms with custom avatars can foster real-time interaction and teamwork between students and teachers across geographical boundaries.

Personalising the learning journey

Adaptive learning environments: Implement platforms that dynamically adjust learning content based on student progress. If a student struggles with a physics concept, the environment can present more practical examples or interactive simulations for better understanding.

AI-powered Tutors: Integrate intelligent AI agents into the metaverse. These virtual tutors become personalised learning companions, providing explanations, answering questions, and guiding students through lessons at their own pace.

Gamified Engagement: Harness the power of gamification by incorporating missions, challenges, and reward systems. This approach fuels student motivation and increases engagement with the learning material.
Real-time feedback loop: Utilise data analytics to provide immediate and personalised feedback. Track student interactions in the virtual environment, evaluate performance in simulations, and offer targeted suggestions for improvement or exploration of new topics.

Real-time feedback loop: Utilise data analytics to provide immediate and personalised feedback. Track student interactions in the virtual environment, evaluate performance in simulations, and offer targeted suggestions for improvement or exploration of new topics.

Addressing Challenges and Expanding Horizons

VR for young learners: Advocate for VR hardware manufacturers to prioritise child-friendly ergonomics. This includes developing lighter headsets and improving refresh rates to minimise discomfort and nausea in younger students.

Open-source VR content creation: Promote the development of a multi-platform VR application server. This democratises content creation by allowing educators and developers to easily build and share VR experiences, fostering a broader range of educational VR applications.

3.14. Summary

Jackie Toal

This chapter has aimed to provide insights and overview of the best potential trends in immersive technologies that can be implemented into teaching practice and that align with the Digital Education Action Plan. These trends include some examples of current research, potential challenges, and some recommendations for educators. These aim to provide a generalised scope of suggestions for potential integration into the curricula.

References

Abdelouahab, A. (2020): Virtual reality–enhanced soft and hard skills development environment for higher education, in The Proceedings of the Third International Conference on Smart City Applications, Cham, p. 255-267.

Aguilera, J. (2014): Mindful embodiment in synthetic environments. Metaverse Creativity, 4(1), p. 5-14.

Alshumaimeri, Y. (2023): Gamifying the Learning Experience Using Extended Reality Technologies for Teaching English as a Foreign Language, Preprint, doi: 10.22541/au.170135394.41598910/v1.

Bamberger, J., Schön, D. A. (1983): Learning as Reflective Conversation with Materials: Notes from Work in Progress, Art Education, 36(2), p. 68–73, https://doi.org/10.1080/00043125.1983.11653404.

Barrows, H. S., Tamblyn, R. M. (1980): Problem-based learning: An approach to medical education (Vol. 1), Springer Publishing Company.

Boland, B. (2023): Extended reality vocational training's ability to improve soft skills development and increase equity in the workforce. AI, Computer Science and Robotics Technology.

Castells, M. (2007): Communication, power and counter-power in the network society, International Journal of Communication, 1(1), p. 238-266.

Chatterjee, H. J., Hannan, L. (2016): Engaging the senses: object-based learning in higher education, Routledge.
Glassman, M. (2001): Dewey and Vygotsky: Society, experience, and inquiry in educational practice, Educational researcher, 30(4), p. 3-14.

Checa, D., Bustillo, A. (2020): A Review of Immersive Virtual Reality Serious Games to Enhance Learning and Training, Multimedia Tools and Applications, 79(9), p. 5501–5527, doi: 10.1007/s11042-019-08348-9.

Dyulicheva, Y., Glazieva, A. O. (2021): Game Based Learning with Artificial Intelligence and Immersive Technologies: An Overview.

Eriksson, K., Alsaleh, A., Behzad Far, S., Stjern, D. (2022): Applying digital twin technology in higher education: An automation line case study, Adv. Transdiscipl. Eng, 21, p. 461-472.

Flores-Cáceres, R. et al. (2024): Bibliometric Review on the Application of Holograms in Immersive Environments in the Context of University Teaching, 2013-2023, International Journal of Learning, Teaching and Educational Research, 23(3), p. 169-185.

Glassman, M. (2001): Dewey and Vygotsky: Society, experience, and inquiry in educational practice, Educational researcher, 30(4), p. 3-14.

Herrington, J., Reeves, T. C., Oliver, R. (2014): Authentic learning environments, New York, p. 401-412.
Huda, M., Maseleno, A., Teh, K. S. M., Don, A. G., Basiron, B., Jasmi, K. A., Mustari, M. I., Nasir, B. M., Ahmad, R. (2018): Understanding Modern Learning Environment (MLE) in big data era, International Journal of Emerging Technologies in Learning, 13(5), p. 71-85.

Jisc (2020): Learning and teaching reimagined. A new dawn for higher education?, https://repository.jisc.ac.uk/8150/1/learning-and-teaching-reimagined-a-new-dawn-for-higher-education.pdf (accessed 29 October 2024).

Lee, K. F., Qiufan, C. (2021): AI 2041: Ten visions for our future, Crown Currency.

Lin, T. J., Lan, Y. J. (2015): Language learning in virtual reality environments: Past, present, and future, Journal of Educational Technology & Society, 18(4), p. 486-497.

Luckin, R., Holmes, W. (2016): Intelligence unleashed: An argument for AI in education.

Mintz, J., Holmes, W., Liu, L., Perez-Ortiz, M. (2023): Artificial Intelligence and K-12 Education: Possibilities, Pedagogies and Risks, Computers in the Schools, 40(4), p. 325-333.

Phakamach, P., Senarith, P., Wachirawongpaisarn, S. (2022): The Metaverse in Education: The Future of Immersive Teaching & Learning, RICE Journal of Creative Entrepreneurship and Management, 3(2), p. 75.88, https://doi.org/10.14456/rjcm.2022.12.

Pinto, R., Peixoto, B., Melo, M., Cabral, L., Bessa, M. (2021): Foreign Language Learning Gamification Using Virtual Reality. A Systematic Review of Empirical Research, Education Sciences, 11(5), 222, https://doi.org/10.3390/educsci11050222.
Nicholson, H. (2024): AI: Empowering Inclusive Education. AI, https://nationalcentreforai.jiscinvolve.org/wp/2024/01/09/ai-empowering-inclusive-education/ (accessed 29 October 2024).

Nisiotis, L., Lyuba Alboul. (2021): Work-In-Progress-An Intelligent Immersive Learning System Using AI, XR and Robots, 2021 7th International Conference of the Immersive Learning Research Network (ILRN), https://doi.org/10.23919/ilrn52045.2021.9459358.

Obae, C. (2024): AI-Powered Metaverse: Shaping the Future of Mixed Reality. EDUCATIONAL AI, https://educationalai.eu/f/ai-powered-metaverse-shaping-the-future-of-mixed-reality (accessed 26 March 2024).

Polikarpus, S., Bøhm, M. Ley, T. (2019): Training Incident Commander's Situational Awareness. A Discussion of How Simulation Software Facilitate Learning, in Digital Turn in School. Research, Policy, Practice, p.219-234, https://www.researchgate.net/publication/333606593_Training_Incident_Commander%27s_Situational_Awareness-A_Discussion_of_How_Simulation_Software_Facilitate_Learning, (accessed 20 October 2024).

Polikarpus, S., Luik, P., Poom-Valickis, P., Ley, T. (2022): The Role of Trainers in Implementing Virtual Simulation-based Training: Effects on Attitude and TPACK Knowledge, Vocations and Learning, 16, p. 1-28, https://www.researchgate.net/publication/370774926_The_Role_of_Trainers_in_Implementing_Virtual_Simulation-based_Training_Effects_on_Attitude_and_TPACK_Knowledge (accessed 20 October 2024).

Pomerantz, J. (2019): Teaching and learning with extended reality technology. Information and technology transforming lives: connection, interaction, innovation.

Qayyum, A., Muhammad Atif Butt, Argani, H., Usman, M., Halabi, O., Ala Al-Fuqaha, Abbasi, Q. H., Muhammad Ali Imran, Qadir, J. (2023): Secure and Trustworthy Artificial Intelligence-Extended Reality (AI-XR) for Metaverses, ACM Computing Surveys, https://doi.org/10.1145/3614426.

Rangel-de Lázaro, G., Duart, J. M. (2023): You Can Handle, You Can Teach It: Systematic Review on the Use of Extended Reality and Artificial Intelligence Technologies for Online Higher Education, Sustainability, 15(4), 3507, https://doi.org/10.3390/su15043507.

Sinai, O. (2024): How AI is Making Immersive Experiences More Powerful, Rock Paper Reality, https://rockpaperreality.com/insights/ar-development/how-ai-is-making-immersive-experiences-more-powerful/ (accessed 29 October 2024).

Suzuki, R., Mar Gonzalez-Franco, Sra, M., Lindlbauer, D. (2023): XR and AI: AI-Enabled Virtual, Augmented, and Mixed Reality, https://doi.org/10.1145/3586182.3617432.

Swiecki, Z., Khosravi, H., Chen, G., Martinez-Maldonado, R., Lodge, J. M., Milligan, S., Selwyn, N., Gašević, D. (2022): Assessment in the age of artificial intelligence, Computers and Education: Artificial Intelligence, 3, 100075.

Tegoan, N., Wibowo, S., Grandhi, S. (2021): Application of the Extended Reality Technology for Teaching New Languages: A Systematic Review, Applied Sciences, 11(23), 11360, https://doi.org/10.3390/app112311360.
The National Urban Security Technology Laboratory (NUSTL) (2024): Virtual Reality (VR) Training Systems for First Responders. Market Survey Report, Science and Technology, https://www.dhs.gov/sites/default/files/2024-02/24_02_29_st_virtualrealitymsr.pdf.

Tuchscherer, R. (2019): Walmart uses virtual reality to test new store manager, USA Today, https://eu.usatoday.com/story/tech/2019/07/08/walmart-uses-virtual-reality-hire-new-managers/1635311001/ (accessed 29 October 2024).

Tuomi, I., Cachia, R., Villar-Onrubia, D. (2023): On the futures of technology in education: Emerging trends and policy implications, Publications Office of the European Union, https://data.europa.eu/doi/10.2760/079734.
Watts, S. (2020): Enhancing Soft Skills Training With Virtual Reality, https://trainingindustry.com/articles/learning-technologies/enhancing-soft-skills-training-with-virtual-reality/ (accessed 29 October 2024).

Wijkmark, C. H., Heldal, I., Metallinou, M. M. (2023): Virtual Simulation for quality assurance of training for officers in the rescue service (Virtuell Simulering för kvalitetssäkring av träning för befäl inom räddningstjänsten), Conference: Framtidens Skadeplats 2023, https://www.researchgate.net/publication/376467998_Virtuell_Simulering_for_kvalitetssakring_av_traning_for_befal_inom_raddningstjansten (accessed 20 October 2024).

Wijkmark, C. H., Heldal, I., Metallinou, M. M. (2023): XR for skills training: Opportunities and challenges for firefighter training (XR för färdighetsträning: Möjligheter och utmaningar för träning av brandmän), Conference: Framtidens Skadeplats 2023, https://www.researchgate.net/publication/376471607_XR_for_fardighetstraning_Mojligheter_och_utmaningar_for_traning_av_brandman (accessed 20 October 2024).

Wijkmark, C. H., Heldal, I., Metallinou, M. M. (2021): Remote Virtual Simulation for Incident Commanders. Cognitive Aspects, Applied Sciences, 11(14), 6434. https://www.researchgate.net/publication/353219474_Remote_Virtual_Simulation_for_Incident_Commanders-Cognitive_Aspects (accessed 20 October 2024).

Xing, Y., Liang, Z., Shell, J., Fahy, C., Guan, K., Liu, B. (2021): Historical data trend analysis in extended reality education field, in 2021 IEEE 7th International Conference on Virtual Reality (ICVR), p. 434-440.

Yanes, N., Bououd, I. (2019): Using Gamification and Serious Games for English Language Learning, in 2019 International Conference on Computer and Information Sciences (ICCIS).

Conclusion

Fırat Sarsar, Jackie Toal

Conclusion

VR technology has attracted more interest than expected in the last 10 years. The most important thing is that this interest has also been recognised in the field of education. Ezawa (2016) predicts that these technologies will be a common technology in 10 years, while Goldman Sachs (2018) thinks that 15 million students will use these technologies in 2025. Today, when looking at the world in 2024, we see that this situation has reached beyond predictions. In fact, there are many variables involved in the use of VR technology, from the Covid-19 epidemic we experienced in the process to the fact that technologies have become more advanced. The frequent use of instructional technologies during the Covid pandemic has increased the number of technology users. In addition, day by day, the low prices of new technologies, such as VR technology, have led to the use of these technologies at home. Educational institutions have also become more generous in purchasing these new technologies. In addition, the development of new technologies, such as the capacity, price, and speed of these technologies, has enabled the integration of these technologies into many institutions and sectors (Güler and Sarsar 2019).

While VR has caused new technologies to enter our lives, it has also made new terms a part of our lives. Immersive learning is one of the most commonly used of these concepts. So far, in this publication, you have learned detailed information about both the theoretical and practical applications of VR technology. You have also received detailed information on instructional outputs for immersive learning. This information shows that immersive learning is not only an output of VR technology but also the beginning of a new learning journey. The basis of learning and teaching processes is the delivery of information in the most efficient and effective way to meet the needs of learners. In this case, learning processes can become more meaningful by transmitting information with effective new technologies. Immersive learning offers an effective learning environment and process for the transmission and retention of information. In this context, it is important to "feel the learning" and to be "part of the learning ". This importance makes the information learned more valuable.

Knowledge was important in the past and will be important in the future. Another important point is how the information is delivered. For this reason, immersive learning will be among the topics to be discussed in the future. VR technology will develop itself, and its applications will diversify. This diversity will affect all areas of learning, and its use will increase. The important thing is how ready the practitioners and developers are for this process. It is important that teachers use VR technologies effectively and that developers design need-oriented applications. For such studies, it is important that practitioners and developers work in close contact and in cooperation.

In summary, this document has aimed to provide a diverse range of methodologies, strategies, innovative pedagogical approaches, and best practice case studies.

In chapter one the aim was to provide an overview of pedagogical approaches, techniques, and specific tools for implementation in current practice, as well as explore some current examples within various schools, higher education institutions, vocational learning, and universities. The aim of the chapter was to inspire educators and provide some strategies and approached in terms of pedagogical and design considerations. The chapter explored the use of XR for experiential learning, immersive storytelling, inquiry based learning, virtual environments for learning, UX principles for designing immersive experiences, as well as possible tools, steps to implement, and use cases of immersive learning.

In chapter two various innovative and inspiring examples of best practices are highlighted from various educational institutes in Europe. These show breadth and diversity in terms of practice, as well as core benefits and how they have been implemented and disseminated within the European educational community.
The final section explores trends as well as highlights some current research practices within the immersive learning realm encompassing AI for XR.

Immersive learning has potential for promoting accessibility, enhancing sustainability, and providing more inclusive learning. The future trends and recommendations highlight directions for future development that align with the European Digital Education Action Plan. This document aims to provide a platform of knowledge for educators and inspiration for future implementation in their own practices.

References

Güler, M., Sarsar, F (2019): Eğitimde Sanal Gerçeklik Uygulamaları, in Akkoyunlu, B., İşman, A. ve Odabaşı, H. F. (eds), Eğitimde Teknoloji Okumaları içinde, p. 311-330.

Ezawa, K., Danely, C. (2016): Virtual & Augmented Reality, in Investment Themes in 2016, p. 52-57, https://ir.citi.com/UEfBZ0oas9qLzjz9EjXThOLsmRLtDgNWGwJItg1klVIGIVm8iFTGvkYnWQPFZ41DjNzOSXl9kuQ%3D (accessed 25 April 2024).

Goldman Sachs (2018): Profiles in innovation report, http://www.goldmansachs.com/our-thinking/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf (accessed 25 April 2024).

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