A PRACTICAL GUIDE TO VR

About the project

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Executive Summary

This booklet contains **empirical and theoretical information useful for decision-makers educators, instructors and trainers inside higher education context who want to deepen their knowledge about Virtual Reality technology** and its practical application inside a university context.
The booklet, titled A Practical Guide to VR, was produced within the framework of the European Research VRChem project as part of Work Package 2. It was written by **METID – Learning Innovation of Politecnico di Milano University** with the supervision and review support of the project consortium.

The booklet is divided into four sections:

Chapter 1 introduces the concept of VR (Virtual Reality) Technology, its theoretical definitions and the effects of its implications inside the educational realm. A short narrative review from academics is presented, reporting benefits of the application of this technology in the learning environment. Different perspectives on the technology are given, not only focusing on headsets but presenting as well other devices, systems, software involved in the use of the technology. Applicative case studies cited from the partners' experience in university are reported, as examples of VR inside educational systems.

Chapter 2 guides teachers in designing effective VR-based learning experience.
It begins with defining clear Intended Learning Outcomes (ILOs). Next, it explains how to design assessment task aligned with those outcomes. Teachers are guided to create VR-supported activities that promote engagement. The chapter stresses alignment between ILOs, activities, and assessments. It offers practical tips for planning and classroom integration.

Chapter 3 presents information not from a theoretical perspective, but from the empirical observation POLIMI (Politecnico di Milano University) has conducted inside its laboratories since the introduction of VR systems in them. This part of the booklet aims to report the university experience to serve as an example for other instructors and educators, or decision-makers inside educational contexts, who want to introduce VR in their classes.
Roles and stakeholders involved are presented, as well as hardware and software configurations to manage several classes inside the laboratories. Finally, monitoring tools such as in-presence forms, post-lesson questionnaires and reports are presented, as strong suggestions given.

Chapter 4 works as an appendix to the previous chapter, detailing the preparatory material that POLIMI has developed over the years for educators and students to best prepare for a VR-enhanced class. Guidelines for both educational stakeholders have been provided, and their usefulness is described in the final chapter.

The booklet serves as a work presenting theoretical and practical perspectives on the application of VR technology inside the educational field, even in front lines with educators and trainers.

Glossary

AR - Augmented Reality

AV - Augmented Virtuality

CAVE - Cave Automatic Virtual Environment

DPIA – Data Protection Impact Assessment

HMDs – Head-Mounted Displays

ILOs – Intended Learning Outcomes

LMS – Learning Management System

METID – Learning Innovation of Politecnico di Milano University
www.metid.polimi.it

MR – Mixed Reality

POLIMI – Politecnico di Milano University (Italy, Milan)

STEM - Science, Technology, Engineering and Mathematics

TLAs – Teaching and Learning Activities

VR – Virtual Reality

VR Labs – usually refers to the VR Laboratories developed inside Politecnico di Milano

VRCHEM – European Erasmus Project for the Investigation on the Innovative Integration of Virtual Reality in Chemical Engineering Education

VRISE – Virtual Reality-induced Symptoms and Effects

XR – Extended Reality

Roadmap

PHASE	TASK	DEEPEN
Understanding VR basics and opportunities inside educational field	Introducing the technology, its theoretical context, and its main advantages and impact inside the educational realm	Chapter 1
Designing the VR experience and curriculum integration	Reformulating and/or enriching existing Intended Learning Outcomes course including soft skills acheivement, emotional and psychomotor abilities improvement. Redefining assessment tasks and teaching and learning activities aligned with constructivist principles	Chapter 2
Implementing the experience	Developing lesson plane, identifying how VR will be used within the class, piloting the VR lesson, provide guidance & support.	Chapter 2
Selecting and developing VR tools and reources	Choosing the most suitable VR platform, building components, evaluating accessibility & cost and etsting the VR environment by yourself to understand navigation, interaction, and pontential issues	Chapter 3
Evaluating and Scaling	Looking at how other have used monitoring and managing tools and forms to organize as best as possible the classes displaced thorugh VR technology	Chapter 4

01

Virtual Reality, Overview and Technology

Over the past decades, immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) have been widely adopted across diverse domains, ranging from military applications to gaming, from artistic and cultural sectors to entertainment, and increasingly within education, among many others. The widespread integration of these technologies across various fields has been facilitated by their capacity to enhance user experience, engagement, and interaction across multiple applications. Furthermore, their adoption has been driven by the significant advantages they offer in real-life simulations, including efficiency gains in terms of time, energy, and financial resources.

Within the field of education, numerous studies have highlighted the benefits of VR in enhancing the learning experience. By fostering deeper engagement, improving knowledge retention, and enabling experiential learning, VR has shown strong potential to transform traditional pedagogical approaches.

This introductory chapter provides a comprehensive overview of VR technology, outlining its fundamental principles, general applications, and the key display systems and devices utilized in VR environments. Additionally, it explores the specific advantages of immersive European research consortium to illustrate their impact and effectiveness in enhancing learning outcomes.

1.1 Definition of VR

The term Virtual Reality was first introduced by Jaron Lanier in 1986, and its conceptualization has evolved over time in response to technological advancements. (Berkman, 2018).
Schroeder (1996) defines VR as a computer-generated environment that fosters a sense of presence, allowing users to interact within a digital space distinct from their physical surroundings. Similarly, Glännfjord et al. (2017) describe VR as a simulation that generates a realistic-looking virtual world,

while Levy et al. (2016) emphasize its interactive nature within a three-dimensional, computer-generated environment.
These and other definitions converge on key concepts such as presence, stimuli, sensory perception, interaction, and environment, all of which are fundamental to immersive experiences in VR. (Spallazzo & Ceconello, 2024).
A crucial theoretical framework in this domain is the Virtuality Continuum, introduced by Milgram and Kishino (1994), which delineates the broader category of Extended Reality (XR) technologies. Their continuum conceptualizes a spectrum of visualization systems, ranging from fully immersive Virtual Reality (where the user is surrounded by a digitally constructed environment) to Tangible Reality, the physical world in which we typically operate without the technical mediation of any device. Within this spectrum lie Mixed Reality (MR) technologies, which integrate both virtual and real-world elements.

These include, in between other technologies, Augmented Reality, where digital artifacts overlay the physical environment, and Augmented Virtuality, where tangible objects are incorporated into a predominantly virtual space. Collectively, these technologies constitute the broader XR landscape.

This booklet, however, specifically focuses on VR and its applications in education, where its immersive, interactive, and engaging characteristics play a pivotal role in shaping learning experiences. To better understand the use of this technology inside the educational realm, next chapters look at the devices typically used for the VR activities, and the software and applications related.

1.2 Devices and categories inside VR technology

VR technology can be deployed using various display systems and devices, including head- mounted displays (HMDs), projection-based systems, loudspeakers, and other sensory-related technologies. It is essential to highlight that immersive environments extend beyond visual perception, incorporating auditory, tactile, olfactory, and even, for example, thermal or humidity-based stimuli, depending on the specific devices and systems utilized.

In contemporary artistic and entertainment installations, immersive experiences increasingly explore unconventional sensory engagement and computerized physical actuators through the integration of perfumes, lasers, or steam, broadening the scope of sensory immersion.

When referring to VR, the term typically denotes virtual environments composed of digital 360° or 180° visual and auditory stimuli. These experiences can be delivered through fully immersive, semi-immersive, or non-immersive systems, each varying in the level of sensory engagement they provide. (Martirosov et al., 2021)

Fully immersive systems offer a 360° simulation that completely envelops the user within a digital environment. This category includes HMDs (e.g., Meta Quest 2/3, Apple Vision Pro, HTC Vive) and CAVE systems, which utilize multiple projectors or screens to surround the user. Audio immersion is achieved through integrated speakers or spatial audio systems, while interaction with virtual elements may involve hand controllers or haptic feedback devices, further enhancing tactile engagement.

Semi-immersive systems utilize screens or projection-based displays that present virtual simulations without fully surrounding the user. While these systems can provide engaging experiences, they do not completely dominate the user's sensory perception as fully immersive setups do.

Non-immersive systems involve handheld devices such as tablets or smartphones, allowing users to navigate virtual environments without direct spatial immersion. These platforms offer a more limited sensory experience compared to their immersive counterparts.

In the context of education, VR-based learning experiences are predominantly facilitated through HMDs. This preference is attributed to the relatively low cost, qualitative effectiveness, and logistical advantages of HMDs, which offer ease of deployment and accessibility for both students and educators. (Jensen & Konradsen, 2017).

In our experience: compared to projection-based or CAVE systems, HMDs provide a more practical and cost-effective solution for fully immersive contents. It enables broader student exposure to VR technology while streamlining organizational and management processes.

1.3 Software and applications

HMDs enable learners to access a diverse range of educational content, tailored to specific pedagogical objectives. **The selection of VR content is highly dependent on the ILOs and the subject matter being addressed.** In some instances, educational activities may require only a 360° video experience, such as a virtual tour of a museum, a historical city centre, or a natural environment. In other cases, more interactive applications may be necessary, such as virtual simulations for mathematical vector analysis, language acquisition exercises, or design-oriented applications that facilitate 3D modelling and sketching.

Additionally, certain educational scenarios may demand highly detailed simulations of laboratory environments or industrial facilities, such as chemical plants, to provide hands-on experiential learning opportunities.

In conducting field research aimed at assessing the current state of VR applications relevant to contemporary educational practices, METID has tried to categorize the available applications. First, a general division in between:

Applications, referring to applicative find on Steam VR or Meta Quest store or similar services, including as well the unique applicative developed inside the university or department.

Platforms, or the services given by third parties that develop custom VR simulation experiences or learning experiences (mainly STEM subjects).

Inside the Applications, we have identified different clusters:

3D sketching app, software dedicated to the creation of three-dimensional sketches, painting operations, realisation of graphic works with VR technology.

3D modelling app, software dedicated to 3D modelling of products, architecture, interiors, urban planning.

Building VR app, software and platforms dedicated to the development of models/ interactions/environments in VR.

Workspace app: applications that allow the use of virtual spaces in which to organise meetings/presentations/conferences/events with the possibility of using tools that enhance/ accompany work activity.

Virtual spaces app: applications that allow the use of virtual spaces for meetings/events/ exhibitions/conferences for the purpose of dissemination/information/artistic/etc.

Other applicative: regarding more specific VR contents such as chemistry lab simulations, medicine training app, data visualization, BIM software plug-in, applications for learning language and many others.

1.4 VR in education

Immersive technologies, including VR, have become increasingly integrated into various fields, ranging from cultural and artistic sectors to professional training and education. Within the educational domain, these technologies have been progressively adopted in diverse learning contexts, demonstrating their potential to enhance the learning experience and improve educational outcomes. (Beck et al., 2023; Pellas et al., 2020)

The academic recognition of VR's potential in education stems from its ability to provide high levels of immersion and interaction, which are key factors in fostering engagement and facilitating experiential learning. Research findings consistently highlight the positive impact of VR on learning effectiveness. Shute et al. (2017) report studies that demonstrate the benefits of VR integration in educational settings. Similarly, Hamilton et al. (2021) conducted a systematic review that identified significant advantages in cognitive, procedural, and affective learning. Notably, VR applications in education have been linked to increased student engagement and motivation, reinforcing their pedagogical value. (Parong & Mayer, 2018)

A comprehensive review of the literature indicates that fully immersive VR environments enhance learning in approximately half of the cognitive studies analysed, particularly when addressing complex or abstract concepts that require spatial visualization. Furthermore, studies on procedural learning suggest that VR-based training can facilitate skill acquisition, with strong evidence supporting the transferability of these skills from virtual to real-world applications. Despite extensive research on cognitive and procedural learning, the role of VR in affective learning and behavioural change remains underexplored in educational contexts. While immersive VR has been widely studied for its emotional and behavioural impact in non-educational applications, further research is needed to understand its full potential within learning environments. (Concannon et al., 2019).

VR has been established as an effective tool for knowledge acquisition and skill development, demonstrating its value in both theoretical and practical learning scenarios. (Radianti et al., 2020).
Observations conducted by METID at Politecnico di Milano, where VR classes utilizing HMDs have been implemented, further support these findings. Students report high levels of satisfaction and enjoyment, even when engaging with VR content for assessment-related exercises. Additionally, many students express a strong interest in repeating the experience and advocate for the broader adoption of VR-based learning across different courses. These insights highlight the growing demand for immersive educational experiences and underscore the need for continued research and implementation of VR technologies in academic settings.

1.5 Applications in Higher Education

In the context of the European research project VRChem, the consortium has been asked to report case studies regarding the application of VR technology in real-classes situations. Partners reported several situations in which VR has been applied in lessons inside their own educational institutions. Here are some of them and other tables reporting information about other case studies, shared by the consortium, can be found at this link.

ChemXP – University of Aveiro

ChemXP is a multidisciplinary initiative developed through the collaboration of researchers in Multimedia Communication, Computer Science, and Chemistry from both the University of Aveiro and the University of Oviedo.
The primary objective of ChemXP is to design, implement, and evaluate two serious games leveraging mixed reality (MR) technologies —augmented reality (AR) and virtual reality (VR)—to enhance student engagement and comprehension in Organic Chemistry. Specifically, both games focus on assisting students in determining the R/S absolute configuration of enantiomers. The AR-based game incorporates a structured learning experience featuring multiple missions, a narrative-driven approach, an interactive tutorial, a badge reward system, and a physics-based molecular creation tool. In contrast, the VR-based game introduces unique interactive mechanics, including the use of special powers to facilitate learning.
The usability and effectiveness of these games were assessed through a pilot study involving Chemistry students at the University of Aveiro. The AR game was accessed via smartphones, while the VR game was experienced using Meta Quest 2 HMDs.

Fig. 1.5a: ChemXP – University of Aveiro

Virtual Visits to Research Lab in Chemical Engineering – University of Cádiz

Since 2021, the University of Cádiz in Puerto Real, Spain, has been implementing an innovazzztive educational initiative aimed at enhancing student engagement in Chemical Engineering.
This initiative makes it possible to visit teaching and research laboratories related to the Chemical Engineering Bachelor's and Master's program, using VR to provide undergraduate and postgraduate students with an immersive experience in laboratories.

The VR activity is integrated as an optional component following a seminar designed to inform students about the Chemical Engineering Bachelor's and Master's program. By offering virtual visits to laboratories, this initiative allows students to explore research environments remotely, thereby enhancing their understanding of the facilities and research activities within the program. In addition to the laboratories, these virtual tours have been extended to two facilities of interest related to teaching in Chemical Engineering: Wastewater Treatment Plant and Winery.

Summer School - Lodz University of Technology

In Šibenik, a summer school was organized as part of the ATOMIC project, with the primary goal of testing immersive tools developed for soft skills training. The program brought together participants from diverse professional and academic backgrounds to engage in hands-on sessions using cutting-edge VR and AR technologies. The focus was on evaluating how these immersive tools can enhance communication, teamwork, and problem-solving skills in dynamic and realistic scenarios. Participants provided valuable feedback on usability, engagement, and the effectiveness of these tools in replicating real-world challenges.

This summer school not only served as a platform for rigorous testing but also fostered discussions on the broader applications of immersive technologies in education and professional development. The event highlighted the potential of VR and AR to revolutionize soft skills training, making it more interactive, engaging, and impactful. The insights gained will guide further improvements and the integration of these tools into diverse training contexts.

Fig. 1.5b: Summer School- Lodz University of Technology

Virtual Welding Simulator VRTEX 360 – Cracow University of Technology

Since 2021, the Virtual Welding Simulator VRTEX 360 has been integrated into the curriculum at Cracow University of Technology, Poland, benefiting approximately 50students annually in the fields of Civil Engineering, Materials Engineering, andMechanics and Machine Construction.
The initiative leverages Lincoln Electric'sVRTEX® 360 Compact K4914-1 platform to enhance practical training in arc welding.

The simulator provides an immersive learning experience, allowing students to develop welding techniques and acquire muscle memory for precise hand movements, such as maintaining the correct torch angle and movement direction. It enables practice with various welding processes, techniques and materials while eliminating material waste and minimizing energy consumption.
By offering a cost-effective, risk-free environment, the simulator equips students with essential welding skills, process fundamentals and knowledge of different joint types and equipment settings, preparing them for real-world applications.

Fig. 1.5c Virtual Welding Simulator

Lab VR – Politecnico di Milano

As detailed in the following chapters, the Politecnico di Milano has integrated VR into its academic curriculum through specialized laboratories equipped with HMDs. These laboratories provide an immersive learning environment, enhancing educational experiences across multiple disciplines.

The university has established two dedicated VR laboratories, each featuring 15 workstations equipped with desktop computers, monitors, Quest 2 HMDs, and designated spaces to ensure safe usage. Since 2021, these facilities have supported various academic departments, including Chemical Engineering, Design, Architecture, and other Engineering fields, involving hundreds of students in diverse VR-based activities.

Within these laboratories, VR is used to facilitate hands-on training, allowing students to engage with complex technical content in an interactive manner. Whether exploring virtual environments, manipulating digital models, or familiarizing themselves with cutting-edge technology, students benefit from an engaging and dynamic learning approach. The following chapters will provide an in-depth exploration of these laboratories, their pedagogical methodologies, and the impact of VR on academic instruction.

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02

How to integrate VR to curricula

The revision of a course or of part of it to host a specific experimentation through VR tools and environments, requires a dedicated design activity that can have a substantial impact on the curriculum. **Remember that VR it is not meant to substitute other learning approaches or teaching resources, but it is a complementary tool that can enhance learning and connections with other disciplines!**

VR can be integrated into different stages of instruction. For example, VR exploration can be used at the preview stage of a flipped learning approach, while VR creation can be used in co-operative-task projects to deepen the learning by students.

Additionally, immersive VR simulations can support conceptual understanding during direct instruction by visualizing abstract concepts (e.g. molecular structure in chemistry or complex engineering designs), VR-based role-play scenarios can enhance engagement during formative assessment activities, and virtual field trips can provide experiential learning opportunities in otherwise inaccessible environments, such as historical landmarks or remote ecosystems, VR environments can easily simulate production facilities or, for example, chemical plants to be explored by students in a safe, efficient and economical modality. Mechanical engineering practical exercises can be afforded without the need for specific rooms or tools to be provided. Students can use instruments that could be dangerous or hard to reach.

The **multisensorial experience a VR experience** can offer to students, may require to extend your re-design effort to the whole course, re-formulating its ILOs in order to let students achieve knowledge and competences at the high levels of Bloom's taxonomy and adding new objectives linked to psychomotor domain, like the ability to manipulate objects, or affective, like a better self-regulation in experimenting risky situations.
It is also important to consider the **engagement in a multidisciplinary team.**

It can include Higher Education institutional offices that should approve the launch of VR experimentation and a pedagogical expert to support teacher in the effective integration of VR in curricula.

This team should also include VR expert technologists that cooperate with the teacher in the development of the virtual environment and technical staff to install and set up the devices making sure the accessibility for students with disabilities and ensuring equitable access to VR technology for all students. All these elements, that result quite demanding in terms of time and effort, imply that you should carefully plan the whole process of an efficient design and feasible virtual learning experience (A decision matrix is available to support initial decisional phase).

Viitaharju (2023) identifies some elements to take into consideration:

> **To identify** **the most demanding teaching and learning workloads** within each learning objective and find common ground among them to allow for a focused starting point for design;
>
> **To target application areas** **where VR can be easily piloted,** with the potential to gradually scale the developed materials over time;
>
> **To create the learning experience** in a way **that stimulate the creation of connections with previous knowledge and support the re-elaboration** of that knowledge into new concepts, using a variety of content formats to enable resource-efficient creation and easy editing with basic technical skills.

2.1 Overview and main concepts

Introducing VR in education can be challenging for teachers unfamiliar with the technology and its pedagogical context[1], making clear guidance crucial for effective implementation. Unlike conventional teaching tools, VR requires an **understanding of both hardware and software, as well as the immersive nature of the medium**. It is also crucial to manage expectations regarding technological glitches or accessibility issues for all students.

Educators must develop a foundational knowledge of VR's capabilities and limitations to make informed decisions about its integration. Without this understanding, there is a risk of either overestimating VR's potential or underutilizing its unique strengths, leading to ineffective implementation.

[1] The relation between pedagogical context and technology has been investigated by Punya Mishra and Matthew J. Koehler's 2006 TPACK framework, which focuses on technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), offering a productive approach to many of the dilemmas that teachers face in implementing educational technology (edtech) in their classrooms.

For this reason, it is important to establish a multidisciplinary team to work with, that includes VR experts, that can "translate" your needs into technical settings and to propose the possible solutions that better fit your pedagogical project design, and instructional designers, that can help tailor VR applications to your specific learning goals.

So, you will need to act not only as a content expert, but also as a **designer of the overall learning experience**: reworking your teaching requires defining in advance what you want to achieve and how. The next step to integrate an experience on VR in your course, is to set the outcomes you want students to achieve, having in mind that they should be:

- **Aligned with the Curriculum;**
- **Focused on students' needs;**
- **Oriented at keeping students motivated and engaged.**

Once the learning outcomes are clearly stated, it will be possible to design the assessment tasks and teaching activities in which students are involved. The constructive alignment, as devised by Biggs (2003), will support you in doing that.
Before working on the outcomes for VR activity you may be interested in having in mind the following aspects:

Specify the levels of Bloom's Taxonomy[2] you want students to achieve—ranging from basic (remembering, understanding) to higher-order skills (applying, analyzing, evaluating, creating). VR proves effective in designing practice-oriented learning experiences that target these higher levels, promoting deeper learning while keeping teachers' workload manageable.

The effort you want to devote to create such experience. The more the VR is oriented at offering a "learning by doing" and immersive experience, the more (time, cost, etc.) is required to the development of its design elements (e.g.: interaction with objects, assembling, moving around, etc.).

The attentive choice **of the pedagogical framework that guide the design** of the whole VR experience. In this sense, technology must be subordinated to the learning design process.

[2]Bloom's Taxonomy is a framework that classifies educational learning objectives into six hierarchical levels of cognitive skills: **Remembering** : recalling facts and basic concepts; **Understanding**: explaining ideas or concept; **Applying**: using information in new situations; **Analyzing**: breaking information into parts to explore patterns and relationships; **Evaluating**: justifying decisions or opinions; **Creating**: producing new or original work.

You can take into consideration the following table to clarify yourself the opportunities you may have.

TEACHER EFFORT LEVEL	*MAIN OBJECTIVE* *(but not limited at)*	*VR OPPORTUNITIES*	*TOOLS* *(examples, not limited at)*
LOW; Utilizing pre-made VR content and applications	ENGAGEMENT; To increase student interest and participation	Pre-made content libraries; Access to a wide range of existing VR experiences that align with various subjects, suitable for low-effort integration	**ThingLinkVR** While not fully open-source, some features allow easy embedding of 360° images and videos
MODERATE; Customizing existing VR platforms or content	ENHANCEMENT; To deepem understanding of complex cocnepts	Collaborative development tools; Platforms that allow teachers to work together in creating or modifying VR content, suitable for moderate effort	**A-Frame (by Mozilla)** An open-source web framework for building VR experiences using HTML-like markup; easy to adapt existing content **Delightex** Not fully open-source, but offers classroom-friendly tools for modifying 3D scenes; some integration possible via APIs
HIGH; Creating original VR content from scratch	EXTENSION; To apply knowledge in real world contests or explore topics beyond the standard curriculum	Advanced creation tools; Software that enables teachers (together with developers) to build comprehensive VR environments tailored to specific educational needs, requiring high effort	**Unity + XR Interaction Toolkit** While Unity is not open-source, many open-source libraries (like MRTK or VRTK) can be integrated into VR projects **Blender (for 3D modeling)** Open-source 3D creation suite used for creating assets used in customs VR environments **OpenXR** Open standard API for VR/AR development; enabling cross-platform VR creation with open-source support

To be effective in helping students to achieve the ILOs, VR experience should offer an experience where users feel **fully engaged and present within a virtual environment.**

Immersive experiences, that usually present, for example, high level of reproduction fidelity of objects (see full list of characteristics just below), lead to "a sense of presence" (feeling of "being there") that can generate a positive impact on their motivation. (Ochs, 2022)

Anyway, low-immersion system, such as desktop VR, are capable of providing high-presence experience to users as well (Núñez, 2004), as "**be present and engaged"** involves a combination of **technological, cognitive and emotional factors** that influence motivation, stimulate deep reflection, facilitate knowledge retention and skill development and, finally, bring students to achieve the course ILOs.

Saying that, it is possible to identify the **key elements you can take on board** in the design of the VR environment and activities to be conducted in it. Consider as starting point the definition of a **thoughtful instructional design framework,** while, the other elements, can be balanced differently based on the ILOs to achieve and the effort you (and your team) can devoted on such activity:

Structuring the experience through **a clear pedagogical framework** that can enhance reflective learning and knowledge connection (Fowler, 2015);

Active learner interaction, that refers to the degree of embodiment via avatars, enabling communication, emotional expression, and object manipulation. Interaction refers to actions and gestures on objects (like rotating, assembling, grabbing and obtain real-time feedback on action) or exploration in the environment, as well as interaction with other users to complete collaboratively a task, for example;

Multisensory engagement through visual (high-resolution graphics, etc.), auditory, tactile (haptic feedback devices that provide physical sensations), movement (seamless tracking of user movements);

Providing users **immediate feedback** after their actions in the virtual environment and with objects, to support contextual adjustments in decisions made during the experience.
Scaffolded difficulty levels allow a progression at an appropriate pace. All these elements promote metacognition, self-regulation and problem-solving skills favouring the user control on his/her experience;

Emotional engagement through compelling narratives or scenarios and social presence;

Representational fidelity, that means the realism of the environment, including visuals, object behaviour, communication. Realism encompasses not only the visual aspects of the display but also the consistency of object behaviour, the authenticity of communication and available interactions, and the overall quality (both in behaviour and appearance) of the user representation.

To deepen:

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? British journal of educational technology, 46(2), 412-422.

DOI: https://doi.org/10.1111/bjet.12135

This paper critiques the integration of VR in education, arguing that while VR offers potential for immersive learning, its adoption often lacks a clear pedagogical framework. It emphasizes the need for a structured approach to ensure that VR enhances educational outcomes effectively.

Núñez, D. (2004, November). How is presence in non-immersive, non-realistic virtual environments possible? In Proceedings of the 3rd international conference on Computer graphics, virtual reality, visualisation and interaction in Africa (pp. 83-86).

DOI: https://doi.org/10.1145/1029949.1029964

This paper explores how presence can occur in non-immersive, non-realistic virtual environments. It suggests that presence is not solely dependent on immersion or realism but can be influenced by cognitive factors such as attention and working memory. The study argues that even in less immersive settings, users can experience a sense of presence if they allocate sufficient cognitive resources to process the virtual environment

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, Article 103778.

https://doi.org/10.1016/j.compedu.2019.103778

The authors conducted a systematic review of immersive virtual reality (IVR) in higher education, highlighting its potential to enhance engagement and learning outcomes. The study identifies key design elements and common challenges, such as usability and resource demands. It concludes with a call for more research on long-term effectiveness and pedagogical integration.

2.2 Design the VR experience and curriculum integration

ILOs express **what the learner is expected to know or perform after the completion of a learning opportunity**, for example "Students will be able to replicate the security procedures to access and use a chemical laboratory".

No matter what effort you are envisioning, the first step is to **set the outcomes you want students to achieve**, as they direct the design of meaningful, value-added assessment tasks and teaching and learning activities.

2.2.1 Intended Learning Outcomes: why are they important?

Effective ILO's formulation works as a guidance in the simulation design and in replying to certain questions such as:

- **What should learners know or be able to do? Intended Learning Outcomes**
- **How will learning be measured? Assessment Tasks**
- **How will learners learn? Teaching and Learning Activities**

ILOs flow from course aims and must be consistent with them. Ideally, **the learning outcomes of a course form a roadmap** to the final learning destination: in other terms, taken together, ILOs should present a very clear picture of the purpose of the activities and the course and what the learners will be able to do at the end of them.
ILOs can refer not only to the knowledge and skills concerning course topics (**disciplinary knowledge and subject-specific skills**), but also to **transversal skills and competences**. When working or studying with VR, even affective and psychomotor domains will be affected in some way. VR use can foster self-efficacy and confidence (in the sanitary and healthy sector in particular), peer communication and collaboration, time management (Hickman, 2017; Hafner, 2013; Angel-Urdinola, 2021).
We suggest referring to the ESCO framework[3] for transversal skills and competences (classification of European Skills, Competences, and Occupations) to identify the main categories under which those skills can be organized. This framework takes on board not only cognitive skills but also manual abilities and affective competences (such as resolving conflicts, show empathy, motivate others, etc...).

[3] ESCO Framework https://esco.ec.europa.eu/en/classification/skill_main

DISCIPLINARY KNOWLEDGE
Course/section/lesson topics

TRANSVERSAL COMPETENCES
Skills that are cross-cutting across jobs and sectors and relate to personal and social competences (Cedefop[3])

CORE SKILLS	THINKING SKILLS	SELF MANAGEMENT SKILLS
▪ Mastering languages ▪ Working with numbers and measures ▪ Working with digital devices and applications	▪ Processing information, ideas and concepts ▪ Planning and organising ▪ Dealing with problems ▪ Thinking creatively and innovately	▪ Working efficiently ▪ Taking a proactive approach ▪ Maintaining a positive attitude ▪ Demonstrating willngness to learn
SOCIAL AND COMMUNICATION SKILLS	**PHYSICAL AND MANUAL SKILLS**	**LIFE SKILLS**
▪ Communicating ▪ Supporting others ▪ Collaborating in teams and network ▪ Leading others ▪ Following ethical code of conduct	▪ Manipulating and controlling objects and equipment ▪ Responding to physical circumstances	▪ Applying entrepreneurial and financial skills and competences ▪ Applying health-related skills and competences ▪ Applying cultural skills and competences ▪ Applying civic skills and competences ▪ Applying general knowledge ▪ Applying environmental skills and competences

▲ Tab. 2.2.1: Skills and competences to be considered when formulating Intended Learning Outcomes

When formulating ILOs for your re-designed course and to address at best the development of the VR, don't consider the cognitive domain only but also emotional and psychomotor spheres as well. The **Bloom's taxonomy** describes educational objectives as belonging of three domains:

Affective: it considers how a learner deals with things emotionally, so it includes behaviours indicating attitudes of awareness, responsibility, the ability to listen and respond in interactions with others; and the ability to demonstrate those attitudinal characteristics or values which are appropriate to the test situation and the field of study (for example the perceived learning effectiveness and satisfaction with the virtual environment);

Psychomotor is demonstrated by physical skills or fine motor skills to accomplish tasks or perform movements (coordination, manipulation, speed, use of precision instruments or tools);

Cognitive, related to knowledge and intellectual development. It involves the processes of thinking, understanding, analyzing, applying, evaluating and creating information.

Predefined domains are analytical constructs that are often difficult to distinguish in practice: usually interactions between these domains occurred, blurring their boundaries.
It classifies the different kinds of learning, in each domain, with an increasing degree of complexity, starting from the basic to more complex level.

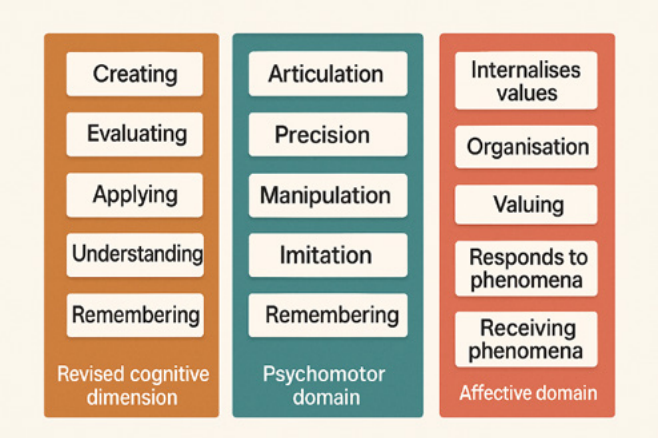


Fig. 2.2.1: Bloom's taxonomy domains. Sources: Bloom et al. (1956); Dave (1970); Anderson et al. (2001).

2.2.2 How to formulate ILOs?

ILOs should be understandable to students and expressed from their point of view, using **"students will be able to"**:

A verb (action expected, that is what kind of activity students will be able to perform);

An object (the content of the action);

If needed: **the context** (where the student will act, that is where students are going to apply the acquired competence);

If possible: **the criterion** for achieving proficiency or, in other terms, how you will know that a student has met the objective.

It is important to fine-tune each ILO by using a meaningful verb that describes what students will be able to do because of the learning process: ideally an **action verb that can be observed and measured**. If you are formulating an ILO, try to ask yourself: "How would I assess it?".
If the ILO suggests to you a clear assessment, that probably means that your ILO is an effective one. When designing the VR experience, it is important to consider all the 3 domains and accurately choose the verbs that describes what you expect students to be able to do upon completion of the learning opportunity.

- **Less effective example**

Students will learn about the key features of a fermentation bioreactor in the three different configurations of batch, fed-batch and chemostat

- **More effective example**

Students will be able to **formulate** the key features of a fermentation bioreactor in the three different configurations of batch, fed-batch and chemostat by applying material balances to the different components and to the cells. [UNDERSTANDING] [APPLYING] [EVALUATING]

Transversal skills

- ***Students will be able to identify*** *and assemble the elements that constituted the three different configurations of a fermentation bioreactor [MANIPULATION] [PRECISION]*
- ***Students will be able to recognize*** *the ethical and environmental implications of fermentation bioreactors and express a commitment to sustainable bioprocessing practices. [VALUING] [INTERNALISES VALUES]*

Inspiration box

Arkansas State University, concrete examples of learning organized by knowledge category on the three domains
https://www.astate.edu/a/assessment/assessment-resource-links/files/Revised-Bloom%20s-Taxonomy-All-Domains.pdf

Examples of verbs for Cognitive, affective and psycomotor domain from Red Deer Polytechnic

Examples of VR use from University of Maryland
https://www.umaryland.edu/fctl/resources/technology/emerging-trends/virtual-reality-vr/#page-1

To deepen:

Maastricht University Institute for Education Innovation (EDLAB). (2016). The UM Handbook for Constructive Alignment.

https://edlab.nl/wp-content/uploads/2022/01/CoAl_PDF_final_version.pdf

The handbook of the Maastricht University Institute for Education Innovation offers practical guidance on aligning intended learning outcomes, teaching methods, and assessment in higher education.
It emphasizes student-centred learning to enhance educational effectiveness and coherence.

Häfner, P., Häfner, V., & Ovtcharova, J. (2013). Teaching Methodology for Virtual Reality Practical course in Engineering Education. Procedia Computer Science, 25, 251–260

https://doi.org/10.1016/j.procs.2013.11.031

This article presents a teaching methodology for integrating virtual reality into engineering education, focusing on enhancing practical skills through immersive learning. Their approach emphasizes increased student engagement and improves conceptual understanding in complex technical subjects.

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. Journal of Computers in Education, 8(1), 1-32.

https://doi.org/10.1007/s40692-020-00169-2

Authors conducted a systematic review examining the effectiveness of Immersive Virtual Reality (IVR) as a pedagogical tool in education. Analyzing 29 experimental studies, they found that IVR often enhances learning outcomes, particularly in complex or procedural subjects, though results vary based on intervention design and assessment methods.

2.3 Assessment Task

Assessment is crucial to support student learning in addition to measuring it. Fit-for-purpose **assessment can test what has been learnt and taught** or, in other terms, it is able to determine whether a student has achieved the ILOs set in terms of disciplinary, psychomotor and emotional knowledge, soft and digital skills. It also promotes student learning by encouraging preparation, engagement in the assessment process, and reflection through feedback.

In addition to that, it helps instructors gain insight into how students are responding to their teaching methods and assess how effectively students are adapting to the VR experience.

The process is transparent and accessible to both staff and students—for example, teachers clearly communicate the purpose, requirements, and expected standards of each assessment task. Students receive focused and constructive feedback, helping them understand how to enhance their performance in the future.
VR assessments differ from traditional assessments in the following keyways:

- **Embodiment and interactivity:** Learning is shown through doing, not just saying or writing.
- **Dynamic evidence collection:** Teachers can analyze behavioural data, decision paths, and spatial interactions.
- **Context-rich scenarios:** Students respond to complex, changing environments, which demand critical thinking and adaptability.
- **Feedback loops:** VR enables immediate feedback through simulation responses, offering more opportunities for formative assessment.

Unlike traditional learning environments, VR allows students to immerse themselves in complex, interactive scenarios that mirror real-world contexts where they can navigate environments, make decisions, manipulate objects, and solve problems. So, it is important, from one side, to promote a system able to foster expertise development while acting in VR and, on the other side, an authentic assessment able to evaluate acquisition of transversal skills, emotional and psychomotor competences other than cognitive knowledge, task completion or artifacts.

During the design phase, it is needed to work on:

- **Targeting performance:** providing real-time feedback to let students immediately understand the consequences of their actions. For example, blocking student progress after a mistake until it has been corrected (Sankaranarayanan et al., 2018; Fracaro et al., 2021) or showing the explosive effect

on an industrial plant setting certain parameters incorrectly;

▪ **Targeting the self-regulated learning behaviour:** integrating self-reflection activities, like self-assessment quizzes, reports on the activity conducted, discussions, etc., during or after a training task to verify understanding and offering more detailed explanations or proposing materials to deepen, in order to foster they ability to manage own thoughts, emotions and actions while acquiring new skills or knowledge. (Panadero, 2017; Zimmerman, 2000)

Thanks to the digital nature of VR and, when effective, the use of headsets and controllers make it possible to automatically track and collect a lot of different data that can offer to instructors (and other stakeholders) an insight on students' performances. Data can refer to the usage, performance and behavioural data, emotion analysis and predictive analytics other than biometric data.

These data, together with tasks results, evaluation of artifacts produced during reflection or debriefing activities, will contribute to a valuable assessment of VR experiences.
It is, in fact, very important to plan for **multiple types of assessment data**, both from within VR (analytics, behaviours, artifacts) and outside it (reflections, discussions, written work) and to adapt **tasks and rubrics to assess both the process and the product**, often combining real-time performance with post-VR interpretation. While these insights can significantly enhance assessment and personalize learning, they also raise concerns about surveillance, data ownership, and informed consent.

Educators must ensure that any data collected is used responsibly, stored securely, and shared only with appropriate stakeholders. It's essential to be transparent with students and guardians about what data is being collected, how it will be used, and for how long it will be retained.
VR can also be used as the location where the assessment takes place. Bogomolova et al. (2021) presented an experimentation in anatomy, where the student must reply to a set of questions focused on subject matters that are difficult to assess on paper (identify structures of the lower leg, determining their spatial relationships and functions, and indicating impaired functions in a clinical scenario). The 10-minute assessment session occurred with real-time interaction between the examinee and assessor during which the examinee must reply to specific questions after manipulating the model.

2.3.1 Assessment functions

The following table proposes some hints about source data that can be collected to achieve specific assessment outcomes and activities that can be designed to collect them aligned to the four core functions of educational assessment: diagnostic, formative, summative, and quality-promoting.

DIMENSION	OUTCOME	TIMING	SOURCE DATA	ACTIVITIES (some examples)
Diagnostic	Planning teaching, gauging students' existing knowledge, misconceptions, and skills	Before learning (before course/ unit/topic)	▪ Prior academic performance or pretest scores ▪ Initial tool selection or task attempts in VR ▪ Navigation patterns and hesitations ▪ Time to complete basic tasks	▪ Drop students into a simulation with no prior guidance to observe instinctive responses ▪ Allow free exploration in a VR and watch what students focus on or avoid ▪ Propose plenary online quizzes to assess prior knowledge or confidence before the VR session ▪ Ask students to narrate their decisions during the first attempt at a VR task
Formative	Reflecting how far the learning outcomes have been achieved to orient learning	During learning (VR experience + reflection activities)	▪ Real-time simulation logs (error, tool usage, pathways) ▪ Frequency of hint use or system guidance ▪ Embedded quiz scores in VR ▪ In-VR audio or text responses ▪ Observational notes from teacher ▪ Student reflection and self-assessments	▪ Include micro-tasks with instant feedback and observation of decision making ▪ After VR activities, ask students to fill out reflection grids or journals (digital or paper) ▪ Organize small group discussions where students explain what they did in VR and why ▪ Stop the simulation at key points to ask questions ▪ Observe students performing task in VR and provide feedback in real time or shortly after
Summative	Assessing the achievement of learning outcomes, grading	After learning	▪ Final outcomes or task completions in VR ▪ Artifacts generated in VR (e.g, 3D models, digital outputs) ▪ Accuracy and complexity of scenario decisions ▪ Video/audio recordings of student VR session ▪ Post-simulation essays or presentations ▪ Rubric-based evaluations	▪ Have students complete a real-world challenge (e.g, design a habitat, manage a business) ▪ Ask students to turn reflections from their VR experiences into formal essays Use standardized rubric to evaluate performance based on recordings or logs ▪ Combine VR experience with a traditional test or oral defense of choices made in VR

Quality promoting	Improvement of teaching / VR tool	After course/ lesson	▪ Aggregate VR performance analytics (e.g, success rates, average time) ▪ Patterns in student reflections or feedback ▪ Heat maps and usage data from VR environments ▪ Teacher/student journal entries and debrief logs	▪ Use VR data to identify curriculum weaknesses and inform revisions ▪ Evaluation tools like: - SUS (System Usability Scale; - SSQ (Measure VR-induced discomfort/sickness); - VRNQ (Evaluate overall VR quality & comfort) ▪ Use platform analytics to see trends and adjust instruction accordingly ▪ Keep logs of what worked well and what did not during VR use

Tab. 2.3.1: Assessment functions in VR with relative's source data and activities

2.3.2. Examples of Assessment Tasks

Below you can explore some hands-on **examples of constructively aligned assessment tasks** that can be applied depending on the ILOs the instructor wants students to achieve.
Tasks described can be part of formative assessment or implemented as elements of summative evaluation that contribute to the course grade.

Hands-on example of constructively aligned assessment task

Intended Learning Outcome
Students will be able to identify and assemble the elements that made up the three different configurations of a fermentation bioreactor

Assessment Task
Reflection grid
Abilities/skills developed: *self-reflection; critical thinking; self-regulation.*
Other abilities: *manipulating and controlling objects and equipment.*

The teacher offers theoretical contents to students explaining the three configurations of the

bioreactor during the lesson and then students must complete a task in the virtual bioprocessing facility. After the VR experience, each student is asked to complete a digital reflection grid (Google Form, LMS quiz, or PDF worksheet) where, for each configuration, they must shortly describe key components used, unique features and application examples.
The instructor can award points upon successful completion.

Into VR Lab
When in the VR lab, students can find formative quizzes to better understand the use and characteristics of each component of the bioreactor and receive immediate feedback after incorrect assemblage of them.

Hands-on example of constructively aligned assessment task

Intended Learning Outcome
Students will be able to identify an unknown compound by interpreting spectral data and simulated reaction behaviour.

Assessment Task
Report
Soft skills developed: Problem-solving, teamwork, data analysis, communication.
Other abilities: precision in using lab instruments.
In small groups, students enter a virtual lab where they are tasked with identifying an unknown compound. Within a timed session, they examine spectral data and run reaction simulations to develop a proposed solution. Afterward, each group submits a brief report describing the steps they followed, their findings, and the reasoning behind their solution. Instructors then evaluate both the process and the final outcome using a rubric.

Into VR Lab
Learning resources (slides, PDF, webpages, etc...) are embedded in VR to look for solution hints. It is also possible to let the system offer rich feedback in case of an unsuccessful run.

Hands-on example of constructively aligned assessment task

Intended Learning Outcome
Students will be able to perform step-by-step procedures safely and accurately for equipment maintenance and inspection in a chemistry plant environment.

Assessment Task

Discussion and multiple-choice test
Soft skills developed: *self-organization; problem solving; stress management.*
Other abilities: *Procedural thinking, attention to detail, safety awareness, psychomotor skills.*

Students are individually placed into a virtual chemistry lab where they must perform the correct equipment maintenance and inspection procedure based on the initial context proposed by the teacher.
The VR system tracks each action. After completion, a performance score is generated based on precision and adherence to protocol and on ability to react to unpredictable situations. Based on results that emerged, the instructor proposes a plenary discussion to highlight challenging steps, compare different decisions taken. After that, a multiple-choice test is proposed to reflect on mistakes or critical tasks/ procedures to be clarified. The teacher may also review the session recording and use a checklist for grading.

In VR lab
Provide self-assessment multiple choice questions integrated in VR for each challenging/crucial topic/task the student is expected to execute.

2.3.3 Rubric

A rubric is a tool that articulates the **expectations for assignments and performance tasks** by sting criteria, and for each criterion, describing the levels of quality. The rubric is a very flexible tool that can be developed for assessing both disciplinary knowledge and soft and digital skills.

A rubric is formed by the following essential parts:

- **the list of the criteria to be used for assessing the performance,** ideally linked to the ILOs to be assessed.
- **a scale (and scoring) that describes the level of mastery** (e.g., exceed expectation, meets expectation, doesn't meet expectation or basic, proficient, advanced).
- **the description cf the various levels of performance quality** (performance descriptors) of the components/dimensions at each level of mastery. This element should be as detailed as possible to facilitate self and peer assessment by students. See an applied, concrete example here below. Find an editable example here (see Starter Kit).

Hands-on example of constructively aligned assessment task

Intended Learning Outcome
Students will be able to analyze and report findings from a simulated lab session, applying scientific structure and terminology

Assessment Task
Virtual Lab Report
Following a biology VR lab on enzyme kinetics, students write a structured lab report including objective, methodology, data, analysis, and conclusions. Reports are submitted through the LMS and graded with a rubric focusing on clarity, scientific accuracy, and critical thinking

Example of analytic rubric:
Articulates different dimensions of VR performance on the 3 different domains (cognitive, affective, psychomotor) and on the output (the report) and provides ratings for each dimension: see an example of an analytic rubric as appendix of the following article - Hamid, R., et al. (2012). Assessment of psychomotor domain in materials technology laboratory work. Procedia - Social and Behavioral Sciences, 56, 718–723.

https://doi.org/10.1016/j.sbspro.2012.09.708

Inspiration box

Utica University, Lab notebook grading rubric
https://www.utica.edu/academic/Assessment/new/NB_Rubric.pdf

Alabama A&M University shares a list of rubrics examples to assess different kind of STEM learning outputs - Fas rubrics

https://www.aamu.edu/academics/colleges/agricultural-life-natural-sciences/departments/food-animal-sciences/_documents/rubrics-fas2018.pdf

College of Business and Technology's Assessment Team, rubric to assess student performance in teams

https://wit.edu/sites/default/files/2020-10/Teamwork-Assessment-Rubric.pdf

2.3.4 To resume

BLOOM'S LEVEL	SUITABLE VR TASK TYPES	EXAMPLE TASK	SUGGESTED ASSESSMENT METHODS
REMEMBERING	360° Exploration, Guided Tours	Virtual museum or plant tour	Multiple-choice quiz (inside or post-VR), SUS (System Usability Scale)
UNDERSTANDING	Concept visualizations, VR Tutorials	Observe chemical processes in VR	Embedded questions, SUS +VRNQ (VR Neuroscience +Questionnaire)
APPLYING	Interactive simulations, decisions-based branching tasks	Set process parameter in a lab simulation	Task performance log, error-tracking, in-VR feedback
ANALYZING	Scenario-based diagnostics, data analysis in VR	Interpret reaction pathways or anomalies	Reflective writing, heatmap analysis, collaborative discussion
EVALUATING	Role-play with crytical thinking, simulations with branching outcomes	Assess ethical implications of lab choices	Peer assessment, rubric, behavioural logs, open debriefs
CREATING	VR prototyping, co-design tasks, storytelling	Design a virtual reactor setup or present findings	3D models, project-based output, oral defense in post-VR sessions

▲ Tab. 2.3.4: VR tasks and assessment methods for each Bloom's knowledge level

2.4 Teaching and Learning Activities (TLAs)

Once you have set the outcomes you want students to achieve and defined how students are assessed, the constructive alignment can support you in designing the TLAs: they are crucial to **enable students to develop their capacity to meet assessment criteria** and thereby achieve the ILOs.

How to bring the student to achieve the objectives stated at the beginning of the course?
Now it is time to design and plan activities they must perform both during the VR experience as well as the ones pre and post experience.
It is important to consider the following elements when designing the VR activities integration:

Pre-training: as many users may be not used at VR, it is recommended to plan multiple sessions of VR guided step-by-step training or even free exploration before students perform the real tasks to achieve formulated ILOs. It is also important to organize a prebriefed session where instructions, expectations, and activities are shared with students (see a checklist to support you in designing this phase).
Students can even be invited, before training, to explore the environment and get confident with headset and controllers. This is the ideal phase to identify in some students any problems with 3D perception, stereoscopic vision or sensitivity to motion sickness.

Debrief: it should be a systematic session where learners, guided by a facilitator, identify and express their reactions to the simulation, providing an opportunity for reflection and deep learning (Fanning, 2007). Debriefing may involve feedback from the simulation software, self-debriefing, and/or facilitated debriefing through tools like SUS, SSQ and VRNQ (see table 2.3.1).

Post reflection: enhance knowledge retention and the value of VR in working on high level cognitive skills through subsequent activities that promote deeper conceptual understanding and metacognition, like discussions with peers or instructor, open questions, debates, reflective writing, etc.

Length of VR sessions: for educational purposes, the suggested duration for VR sessions is **between 20 and 70 minutes,** depending on the type of activity, which also influences the ideal length. The higher level refers to the assumption that the VR software meets high quality standards (as assessed by tools like the Virtual Reality Neuroscience Questionnaire, VRNQ) and users are properly familiarized with the system through introductory tutorials. Longer sessions may increase the risk of VR-induced symptoms (VRISE), but these can be mitigated with immersive design features such as better graphics, sound quality, and helpful in-game instructions.

Working in teams: it is a valuable approach in planning activities in VR, primarily because it fosters the development of collaboration and teamwork skills in students.
Secondly, it facilitates the organization of VR facilities, since the number of devices (PCs, headsets, etc.) available for VR experiences is usually smaller than the number of students. In this approach, while one person is exploring the VR environment, the others are assigned different tasks (e.g., studying additional material to support the student in VR, giving instructions to a colleague, etc.) or take on different roles within a more complex activity in which VR represents just one step.

2.4.1 Which framework to (re)design TLAs for accommodating VR?

The most effective instructional methods that can be used when designing a VR experience are mainly linked to constructivist theory principles (Cao et al., 2023) that emphasizes the **active role of learners** in constructing their own knowledge and understanding. In particular:

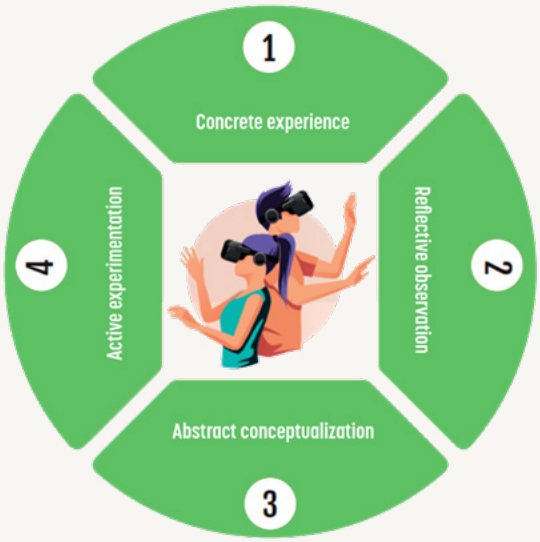
- **Learners actively build upon their existing knowledge** to make sense of new information.
- **Social interactions** with peers, teachers, and the environment play a crucial role in the learning process.
- **Learning is most effective when it is applied to real-world or relevant contexts**.
- **Learners engage** actively with their environment **to construct knowledge with teacher guidance.**

The VR narratives, objects and activities inside can then be structured through different methods.
We go more in depth with a few of them offering some concrete examples on how to set them up.

Examples can be easily adapted to different disciplines:

Kolb's cycle

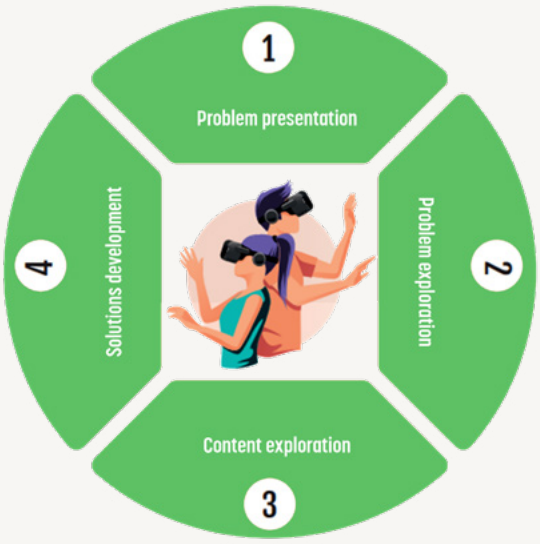
It assumes that learning is a process that creates knowledge through the transformation of experience. The development of new concepts is essentially provided by new experiences, and learning involves the acquisition of abstract concepts that can then be applied flexibly in a variety of situations.



▲ Fig. 2.4.1.1: Kolb's cycle

Problem-Based Learning (PBL)

Problem-based learning is an instructional method where relevant problems lacking a well-defined answer are introduced at the beginning of the instruction cycle and **students learn about the subject through the experience of solving an open-ended problem.**



▲ Fig. 2.4.1.2: Problem-based learning

Inquiry-based learning

Inquiry-based learning promotes student learning through an increasingly **independent investigation of complex questions, problems, and issues:** rather than teaching the results of others' investigations, which students learn passively, the instructor poses one or more meaningful questions and assists students in learning through an active investigation of the topic.

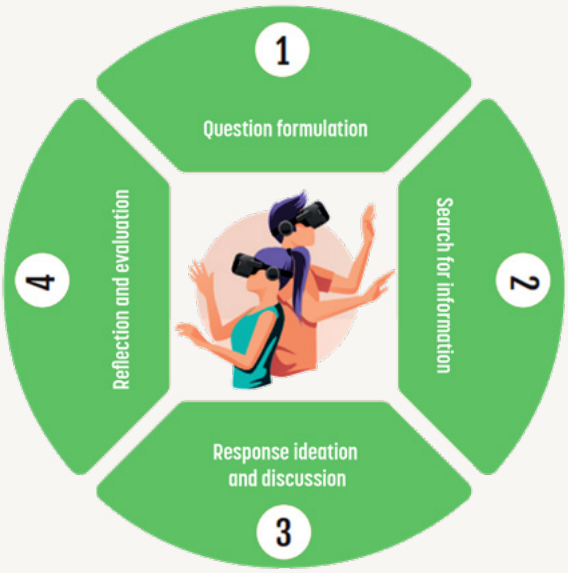


Fig. 2.4.1.3: Inquiry-based learning

Hands-on example of a constructively aligned activity

Kolb's cycle, individual

Intended Learning Outcome
Students will be able to identify and assemble the elements that made up the three different configurations of a fermentation bioreactor.

Assessment Task
Reflection grid

Teaching and learning activities
15′ activity introduction + 30/60′ (depending on the number of devices available) VR training + 30′ VR activity + 30′ reflection + 30′ conceptualization + VR.

Soft skills developed: *self-reflection; critical thinking; self-regulation.*
Other abilities: *manipulating and controlling objects and equipment.*

Concrete experience: during the lesson, the teacher offers a theoretical explanation to students explaining how a bioreactor works, its three possible configurations, etc...

At the end, he/she introduces the VR activity, the task and the modalities to adopt. When in VR lab the teacher invites students to get familiar with the environment and the devices before starting the activity. Then students enter a virtual bioprocessing facility where they interact with a digital interface simulating a fermentation lab. Each of them is tasked with obtaining a pre-determined product that can be obtained based on a different bioreactor setup.

Reflective observation: After the VR experience, each student is asked to complete a digital reflection grid (Google Form, LMS quiz, or PDF worksheet) where, for each configuration, they must shortly describe key components used, unique features, application examples.
The teacher reflects with the students on the experience carried out (retracing the activities, asking questions, etc.).

Must shortly describe key components used, unique features and application examples. The teacher reflects with the students on the experience carried out (retracing the activities, asking questions, etc.).

Abstract conceptualization: The teacher abstracts the process from the practical experience just performed and creates the connection with the theoretical concepts. The conceptualization phase can also be carried out collaboratively, stimulating students to connect the key points of the emerged experience with theoretical concepts, possibly through a shared document or map.

Active experimentation: The students enter the environment again to redo the experience, in the light of what has been discussed.

In the VR Lab
Vergara (2019) recommended, in VR experimental laboratories, to adopt a step-by-step protocol as a method to improve the long-term retention of knowledge.

When in the VR lab, students can find formative quizzes to better understand the use and characteristics of each component of the bioreactor and receive immediate feedback after incorrect assemblage of them.

Low-hanging fruit tip: The teacher can propose a quiz to focalize the main elements of each configuration and the assembly steps before the VR experience.

Hands-on example of a constructively aligned activity
Problem-based learning, in pair

Intended Learning Outcome
Students will be able to safely and accurately perform step-by-step procedures for equipment maintenance and inspection in a chemistry plant environment.

Assessment task
Discussion and multiple-choice test

Teaching and Learning Activity
15′ to introduce VR rules and the activity + 60′ VR training + 30′x2 activity in VR + 30/45′ discussion + 15′ quiz

Soft skills developed: *self-organization; problem solving; stress management.*
Other abilities: *procedural thinking; attention to detail; safety awareness; psychomotor skills.*

The teacher presents the initial problem that occurred in a chemistry plant environment that students, in pairs, should solve. Students are given all instructions and references to conduct the activity and dedicated time to get confident with VR before starting. While one member of the pair works in virtual reality, their colleague guides the activity from their desktop using the material provided by the teacher.
While in VR they have to find out the problem, solve it, and conclude the maintenance and inspection procedure. After completion, a performance score is generated based on precision and adherence to protocol and on ability to react to unpredictable situations.

Based on results that emerged, the instructor proposes a plenary discussion to highlight challenging steps, and compare different decisions taken. After that, a multiple-choice test is proposed to reflect on mistakes or critical tasks/procedures that need to be clarified. The teacher may also review the session recording and use a checklist for grading.

In VR lab
The failure of emergency procedures can be represented by “real” consequences, like explosion, collapse, etc., to let students experiment without any risk.

Low-hanging fruit tip: VR can be implemented as a flipped classroom, allowing students to study and review procedures at home, before class, and then use class time for virtual exercise.

Hands-on example of a constructively aligned activity
Problem-based learning, gamified

Intended Learning Outcome
Students will be able to identify an unknown compound by interpreting spectral data and simulated reaction behaviour.

Assessment task
Group report through rubric

Teaching and Learning Activity
20′ to scenario introduction + 15′ to introduce VR rules and the activity + 60′ VR training and team organization + 30′x3 activity in VR + 30′ debrief + report development at home + 60′ solution presentation and final debrief.

Soft skills developed: *Problem-solving, teamwork, data analysis, communication.*
Other abilities developed: *precision in using lab instruments.*

The teacher presents the real-world problem scenario in which students have to identify an unknown compound based on spectral data and simulated reaction behaviour. Students are given theoretical content they can deepen during VR. In the next lesson, students are then divided into teams and briefed on the competition rules: each team will occupy a VR station and work under a time limit to solve the same problem using digital instruments and analysis tools embedded within the virtual lab. To support their investigation, students have access to a set of learning resources. Teams manage their own workflow by dividing tasks: some members operate instruments in the VR lab, while others review theoretical content and compile findings.

As the session progresses, students collect and interpret spectral data, simulate chemical reactions, and attempt to identify the compound. When time is up, the teacher facilitates a debrief collecting feedback about the virtual experience. Each team works on a group report: through this report each group presents its solution. The report will be finalized at home. The next lesson, teams present their solutions, the teacher explains the correct answer and announces the winning team.

In VR lab
Learning resources (slides, PDF, webpages, etc...) are embedded in VR to look for solution hints. It is also possible to let the system offer rich feedback in case of unsuccessful run.

Low-hanging fruit tip: Encourage students to keep a VR session journal or voice-recorded key observations during the experience for easier report writing.

Here are presented some further hints about VR activity integration:

ACTIVITY	SUBJECT	CONSTRUCTIVELY ALIGNED ACTIVITY
KOLB'S CYCLE IN TEAMS	CLINICAL EMERGENCY MANAGEMENT	**Activity:** Within the simulation, students work in teams, formulate a diagnosis, initiate treatment, and engage with virtual team members to solve the problem. After the activity, team members reflect on their decisions from the perspective of their assigned roles. The teacher facilitates this discussion, highlighting group dynamics and decision-making. Then, the teacher helps students extract general principles from the experience and connect them to the theoretical content of the course. Students re-enter a new virtual scenario, applying their insights and testing their understanding in a similar team-based setting. **Assessment task:** Evaluation is based on mance in the VR scenario, focusing on critical actions, teamwork, and both technical and non-technical skills. Each case is given a score by clinical relevance into a costumized rubric, with a total score and detailed breakdown by skill category. **Hint:** all phases were conducted online through videoconference system. **Discover more at:** https://asmepublications.onlinelibrary.wiley.com/doi/full/10.1111/tct.13727
SCENARIO-BASED LEARNING	TRANSVERSIAL SKILLS +BIOLOGY	**Activity:** Students play Cellverse, a collaborative VR cellular biology game. Participants assume distinct roles (Navigator or Explorer) and work in pairs to solve spatial puzzles by communicating effectively, leveraging their roles and prior knowledge to enhance collaboraion and problem-solving. **Discover more at:** https://upload01.uocslive.com/ISTE/ISTE2019/PROGRAM_SESSION_MODEL/HANDOUTS/112190528/CellverseISTEhandoutdocx.pdf https://www.researchgate.net/publication/336240793_Designing_for_Group_Flow_in_Collaborative_Cross-Platform_Learning_Experiences

INQUIRY-BASED LEARNING	PHYSICS OR OTHER DISCIPLINES	**Activity:** The teacher formulates questions that students will be able to answer after exploring the VR or 360° video. The teacher introduces to the scenario or context himself or asking students to read/watch other resources (articles, videos, books, etc...) and invite students, with different roles in each team, to start to reflect and discuss about the initial questions. Then students start the "virtual travel" and collect information to be able to elaborate a response. Each team shares their answers with the class (orally or through a shared document). The teacher collects the answers and opens a moment of discussion, trying to guide the students towards a common synthesis. The teacher concludes the activity by sharing the correct answer(s): starting from these, he can launch a brief reflection, useful for proposing new content or new questions, in view of the following lessons. **Assessment task** (proposal): Each team writes a comment on each response presentation using the Rose and Thorn technique, specifying what it likes (Rose) and what should be improved (Thorn). **Discover more at:** https://www.nytimes.com/2020/10/29/learning/lesson-plans/virtual-reality-curriculum-guide-experience-immersion-and-excursion-in-the-classroom.html#link-66027f44
GAME-BASED LEARNING	CHEMISTRY	**Activity:** The course is structured to immerse students in the role of a modern chemical researcher, particularly a forensic scientist, using a reflective and experiential learning approach centered around the VR game Dead Herring. It begins with students sharing their initial perceptions of modern chemical research, followed by setting expectations for their role and mindset as researchers. They then individually experience the VR game, reflecting on their methodological approach, chemistry learning, and the immersive experience. Post-game, students analyze their experiences in relation to their initial views, fostering deeper understanding. In the second phase, each student creates innovative teaching materials for school chemistry lessons, incorporating either contemporary chemical concepts or digital tools like VR. **Assessment task:** Peer review through group discussions **Discover more at:** https://pubs.sciepub.com/wjce/9/1/1/

▲ Tab. 2.4.1: Practical hints on how to integrate VR in didactics

2.4.2 Syllabus and lesson plan

It is fundamental to make evident to students the integration of VR, in all its possibilities, in the syllabus of your course (editable template here). The essentials you might focus on are listed below.

Course information: clearly describe the role of VR in the course, including its purpose (e.g., enhancing learning through immersive simulations; potentiating transversal skills, preparing for real laboratory, etc.) and its alignment with learning objectives.

Intended learning outcomes: detail what you want students to achieve not only in terms of knowledge and skills concerning disciplinary knowledge but also the psychomotor and affective domain, as well as in terms of relevant transversal skills.

Course materials and resources: specify hardware (e.g., Helmet-Mounted Display (HMD) and controller, Oculus Rift, HTC Vive), software (Unity 3D, ViRSE API), and supplementary resources like tutorials or textbooks for VR development.

Lab sessions: describe in detail the lab activities. Include schedules for hands-on workshops and independent study. Remember to plan the activities offering time flexibility in fulfilling tasks in VR as users may be so immersed in the experience that they can be distracted. (Cao et al., 2023)

VR pre-training: pre-training activity must be scheduled before the VR experience to familiarize with the hardware and the virtual environment to optimize the time during the "real" lab, as it has been shown to increase knowledge transfer, and self-efficacy. (Meyer et al., 2019)

Pre-briefing: to be organized very closed to the VR activity to share instructions, expectations and activities.

Debriefing sessions: to be scheduled at the end of VR activities to encourage reflection on the knowledge gained (Parong & Mayer, 2018), on how the experience works considering the learning objectives and how was the own learning process (metacognition).

Inclusivity: make clear that all students can access the VR experience through alternatives (e.g., desktop versions) and flexible timelines. Encourage an open environment where students can express concerns or opt for equivalent activities without penalty.

Logistics: provide information on accessing VR labs, equipment availability, troubleshooting support, and timelines for completing assignments. Actively promote the availability of VR resources to students as a supplementary study tool.

Privacy issues: advise students that VR applications may collect personal, behavioural, or biometric data during use and invite them to use VR tools responsibly and be aware of privacy settings and data policies.

Inspiration box

Gannon, K. (2018, September 12). How to Create a Syllabus Advice Guide. The chronicle of Higher Education

https://www.chronicle.com/interactives/advice-syllabus

Pre-briefing Template from eCampusOntario, on healthcare field
https://ecampusontario.pressbooks.pub/app/uploads/sites/1641/2022/02/Table-3.1-Prebriefing-Template-1.pdf

Some examples of debriefing models, and the structure or process they employ are provided in the Virtual Simulation Educator's Toolkit from eCampusOntario

https://ecampusontario.pressbooks.pub/app/uploads/sites/1641/2022/02/Table-5.1-Debriefing-Model-Examples-Based-on-Pivec-2011-Dreifuerst-2012-Gardner-2013-Lusk-2013-1.pdf

2.4.3 Some tools and resources

Bringing AR and VR tools into the classroom doesn't have to be expensive. Available resources, ranging from low-priced viewers like Google Cardboard to cost-effective equipment that can connect to smartphones, can be acquired without breaking the bank.
Online it is possible to find software and digital resources that can be integrated or reused in courses. In the table below, there are listed some free (at that time) tools and resources that can be explored.

TOOL NAME	TYPOLOGY
Labsim https://nova.disfarm.unimi.it/labsim/index_it.htm	LABSIM IS A SIMULATOR FOR INORGANIC ANALYTICAL CHEMISTRY LABORATORIES.
Labxchange https://www.labxchange.org/library	DIGITAL TOOL THAT OFFERS SCIENTIFIC RESOURCES (SIMULATIONS, ASSESSMENTS, VIDEOS, ETC...) TO BE USED FOR CREATING LESSONS. DEVELOPED BY HARVARD UNIVERSITY.
MERLOT https://www.merlot.org/merlot/index.htm	IT PROVIDES SIMULATIONS, AND VIRTUAL LABS ACROSS ANY FIELD OF STUDY.
MoleculARweb https://molecularweb.epfl.ch/	MOLECULARWEB IS A FREE, WEB-BASED PLATFORM THAT USES AUGMENTED REALITY (AR) TO HELP STUDENTS VISUALIZE AND INTERACT WITH 3D MOLECULAR STRUCTURES AND CHEMISTRY CONCEPTS.
Nearpod https://nearpod.com/	TOOL THAT ALLOWS TEACHERS TO DEVELOP LESSON PLANS WITH VR AND AR TECHNOLOGY.
PhET Interactive Simulations https://phet.colorado.edu/	PHET PROVIDES A COLLECTION OF FREE, INTERACTIVE SIMULATIONS THAT ALLOW STUDENTS TO EXPLORE SCIENTIFIC CONCEPTS THROUGH EXPERIMENTATION.
TimeLooper https://www.timelooper.com/	APPLICATION TO VISIT LOCATIONS THROUGH A HISTORICAL LENS.
Unreal Engine https://www.unrealengine.com/en-US	IT IS A REAL-TIME 3D CREATION PLATFORM DEVELOPED BY EPIC GAMES, PRIMARILY USED FOR CREATING VIDEO GAMES, SIMULATIONS, AND INTERACTIVE EXPERIENCES. IT IS PARTIALLY FREE.

VR and simulations from College of Staten Island https://library.csi.cuny.edu/oer/virtuallabs-simulations	COLLECTION OF LABS AND SIMULATIONS THAT FACULTY CAN USE IN THE REMOTE LEARNING CONTEXT, BY THE COLLEGE OF STATEN ISLAND.
VR and simulations from Colorado School of Mines https://libguides.mines.edu/oer/simulationslabs	COLLECTION OF LABS AND SIMULATIONS BY THE COLORADO SCHOOL OF MINES.
360 VR – The New York Times https://www.youtube.com/playlist?list=PL4CGYNsoW2iCGZa3_Pes8LP_jQ_GPTW8w	360 VIDEOS THAT ENABLES IMMERSIVE, REAL-WORLD EXPERIENCES THAT ENHANCE EMPATHY, CRITICAL THINKING, AND ENGAGEMENT.
360Cities https://www.360cities.net/	APPLICATION TO VISIT PLACES AROUND THE WORLD.

▲ Tab. 2.4.2: Free online tools and resources for VR

2.5 Challenges

The adoption of VR by teachers and students is slowed down by challenges like:

TEACHERS' CHALLENGES	LEARNERS' CHALLENGES
LACK OF TECHNICAL SKILLS AND CONFIDENCE TO OPERATE VR EQUIPMENT AND SOFTWARE	DIGITAL LITERACY GAPS AFFECTING ABILITY TO CRITICALLY ENGAGE WITH VR CONTENT
HIGH COSTS OF VR HARDWARE, SOFTWARE, AND MAINTENANCE	UNEQUAL ACCESS TO VR DEVICES, HIGH-SPEED INTERNET, AND SUPPORTIVE ENVIRONMENTS (DIGITAL DIVIDE)
DIFFICULTY IN INTEGRATING VR PEDAGOGICALLY WITH CURRICULUM AND LEARNING OBJECTIVES	HEALTH ISSUES LIKE MOTION SICKNESS, EYE STRAIN, AND DISCOMFORT DURING VR USE
LIMITED AVAILABILITY OF CURRICULUM-ALIGNED, HIGH-QUALITY VR EDUCATIONAL CONTENT	POTENTIAL FOR DISTRACTION AND COGNITIVE OVERLOAD IN IMMERSIVE VR ENVIRONMENTS
INSUFFICIENT IT SUPPORT AND TECHNICAL DIFFICULTIES IN SETUP AND TROUBLESHOOTING	DELAYED OR INCONSISTENT EXPOSURE TO VR LEARNING DUE TO SLOW ADOPTION
TIME CONSTRAINTS TO LEARN, PREPARE, AND IMPLEMENT VR LESSONS	ACCESSIBILITY BARRIERS FOR STUDENTS WITH DISABILITIES DUE TO LACK OF ADAPTIVE VR FEATURES
CONCERNS ABOUT VR EFFECTIVENESS AND CONVINCING INSTITUTIONAL LEADERSHIP	SUBSCRIPTION COSTS AND RECURRING FEES LIMITING CONTINUOUS ACCESS TO VR CONTENT (IF NOT LIMITED TO COURSE EXPERIENCE)
NEED FOR ONGOING PROFESSIONAL DEVELOPMENT AND PEER SUPPORT	OVERWHELMING SENSORY INPUT CAUSING DISCOMFORT OR DISENGAGEMENT
MANAGING CLASSROOM BEHAVIOR AND ENSURING FORMAL COMMUNICATION IN VR SETTINGS	
ASSURING EQUITABLE LEARNING EXPERIENCE TO ALL STUDENTSFORMAL COMMUNICATION IN VR SETTINGS	

Tab. 2.5.1: Challenges in VR integration in didactics

Ensuring that both instructors and learners are prepared to effectively use VR in educational settings requires a structured approach encompassing training, clear communication, and ongoing support. The following strategies are grounded in best practices and real-world examples from educational VR integration.

Offer structured training programs that cover, on one side, the main steps of the design process (VR main concepts, alignment with learning objectives, hands-on practice with VR content, syllabus and lesson plan development) and, on the other side, both technical than pedagogical skills to become more confident with VR application in didactics.

Effective communication and clear guidelines from teacher to students to make them aware about VR integration goals, expectations, support offered and feedback together with protocols and instructions linked to VR use, safety, digital etiquette, privacy.
That means planning initial briefing session to get confidence and final debriefing to increase awareness about what can be improved in the experience designed by the teacher in order to make it more effective and valuable for students.

Ongoing support structured through: IT and VR expert staff able to guarantee assistance during VR use and ensure effective maintenance of tools and devices; peer support and communities of practices for instructors to collaborate, share best practices, and mentor each other inside a dedicated learning management system (LMS) to centralize VR content, track progress, and provide analytics for both instructors and learners.

Blended Learning approaches: Integrate VR with traditional teaching methods to maximize engagement and learning outcomes, rather than relying solely on VR.

2.6 Designing Inclusive VR Learning Experiences

As you begin designing your VR-based learning activities, it's important to consider a range of student needs, including those related to physical, cognitive, sensory, and situational differences.
Start by acknowledging that some learners may experience motion sensitivity or sensory overload in virtual environments. To mitigate these challenges, it's helpful to:

Limit the duration of VR sessions to shorter timeframes (such as 10-15 minutes) and incorporate breaks.

Prioritize user comfort in navigational mechanics: features like teleportation or snap-turning are often preferred over continuous movement.

Avoid rapid motion, flickering effects, and overwhelming visual stimuli.

Offer students the ability to personalize movement settings to their comfort level, when possible.

Accessibility for students with disabilities must also be addressed from the outset. For those with visual impairments, consider to offer alternative formats such as screen-reader-compatible simulations, tactile resources, or descriptive audio walkthroughs.
Learners with mobility impairments should be able to engage fully from a seated position, with input options that include remappable controls or keyboard/mouse support. And for students with photosensitive epilepsy, it is crucial to avoid flashing visual elements and to clearly communicate any potential triggers in advance. **Always offer a non-VR version of the experience when needed.**

Flexible interaction models can make a big difference. Design your experience so that students can participate either seated or standing, depending on their needs. **Incorporate multiple input methods**—such as voice commands, gaze selection, or simplified controllers—**to accommodate diverse motor abilities.**
Tasks should be scaffolded so that learners can progress at their own pace, with opportunities for support and adjustment.

In many cases, not every student will have the same level of access to VR hardware, particularly in hybrid or off-campus settings. To promote equity, consider offering web-based or desktop-compatible alternatives, and select cross-platform tools that allow multiple modes of participation.
If hardware availability is limited, plan for device loan programs or structured access through labs and learning centres.

From an instructional design perspective, **verify that the formulated intended learning outcomes (ILOs) are achievable through both VR and alternative pathways**, even their assessment. Make evident, in the syllabus, the possibility to use VR-alternatives.

2.7 Quick start guide

STEPS	IN-VR	TIME ESTIMATION	STAFF
Decision: Why Use VR	High interactivity, immersion, spatial learning, or real-time simulation		Subject matter expert
Intended Learning Outcomes (ILOs)	To be formulated for disciplinary knowledge and subject-specific skills as well as for transversal skills and competences	0.5 day	Subject matter expert Instructional designer
Assessment Strategy	Embedded VR quizzes, scenario branching decisions, rubrics based on ILOs	2 days	Subject matter expert Instructional designer
Teaching & Learning Activities	Pre-VR: Orientation + objectives In-VR: Simulation, exploration, tasks Post-VR: Reflection, discussion, assignment	1-2 days for design	Subject matter expert Instructional designer
Evaluation Plan	Measure success using: Learning effectiveness (tests, observation) Engagement & usability (feedback forms, heatmaps) Technical performance (crash rate)	Assess ethical implications of lab choices	VR technician Instructional designer Subject matter expert
VR implementation	Build the experience through a dedicated software (e.g. Unity/Unreal)	Depending on the level or reality and interactivity (usually an iterative revision process among VR developer, SME and instructional designer is needed)	VR developer Subject matter expert Instructional designer
VR running	Set up the room, the lesson plan and material to be used, support; conduct the assessment and evaluation	1 day in total Pre VR 60 min In-VR 30 min Post-VR 30 min	Subject matter expert VR technician

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03

Run VR learning experimentation, the Politecnico di Milano experience

This chapter presents insights gained from **METID - Learning Innovation of Politecnico di Milano University,** in the development and management of two VR Labs designed for technology-enhanced lessons. The purpose of sharing this experience is to offer practice-based recommendations and guidelines for decision-makers and educational professionals in various learning environments, supporting the adoption of VR by considering specific contextual factors. The chapter outlines instructional methods, implementation modalities, key observations, and empirically developed tools to facilitate this transition.

3.1 Building up VR Labs

In 2020, the Politecnico di Milano University dedicated two classrooms for educational experimentation with VR. This began with the EYEducation pilot project, developed in collaboration with AVEVA/ Schneider Electric, which integrated immersive Digital Twin experiences into the Industrial Engineering master's program. The project used two software suites: Dynsim, a dinamic simulator of chemical processes, and Eyesim, which offers 3D visualizations of industrial plants (Galeazzi et al., 2024).

Following the project's success, the university expanded from a single VR workstation to a full lab accommodating multiple students. This required identifying appropriate spaces and roles to manage the project. Two rooms on two different campuses of POLIMI University have been identified, and a budget for the building up of the Labs has been set. A total number of 15 workstations in each room had been considered, and each workstation had been associated with an adjacent area, defined by tape lines on the ground, useful to set the "boundaries" of the VR zexperience. This area of around 2mx2m prevents students from hurting themselves and it helps distributing users more precisely in the room space ***(Fig 3.1).***

Fig: 3.1: Layout of the VR Lab, with workstations and boundaries on the floor

3.1.1. Roles involved

Some key roles must be identified for the management of the VR lessons, from the booking of the space to the design of the overall learning activity, to the technical considerations and preparation of the room.

METID Task Force
The METID task force is responsible for managing the VR Laboratories, collaborating directly with faculty on the methodological design of VR-based lessons, and supervising lesson delivery, when necessary. The potential and limitations of VR technology are investigated by METID both through academic research and hands-on experimentation during VR lessons.

Technical Support
The technical support team is responsible for preparing the classroom for VR lesson delivery and providing on-site assistance for each individual workstation in the laboratory. They ensure the proper functioning of both hardware and software components.

ICT Services
A representative from the university's ICT (Information and Communication Technologies) services is consulted whenever there is a need to install new software, update existing applications, implement specific procedures for new digital systems, or modify or enhance the classroom's internet connectivity.

3.1.2. Device considerations

From the hardware point of view, the workstation needed to deliver mid-to-high performance, with particular emphasis on graphical processing, as this component is crucial for rendering complex 3D environments.

Alongside a well-balanced combination of CPU, RAM, and storage capacity, the graphics card had to be optimized for gaming applications—since these typically demand high computational power—and fully compatible with the selected Virtual Reality headset.

Here are the specifications:

Processor: Intel Core i7 10th generation (8 cores, 16M cache, base clock 2.9GHz, up to

4.8GHz) DDR4-2933

RAM: 32 GB DDR4

Primary Storage (SSD): 512GB NVMe solid-state drive

Secondary Storage (HDD): 2TB, 7,200 RPM, 6 Gb/s

Operating System: Windows™ 10 Pro (64-bit)

Network Card: Gigabit Ethernet Controller 10/100/1000 with RJ45 port, supporting PXE protocol and Wake-On-LAN mode

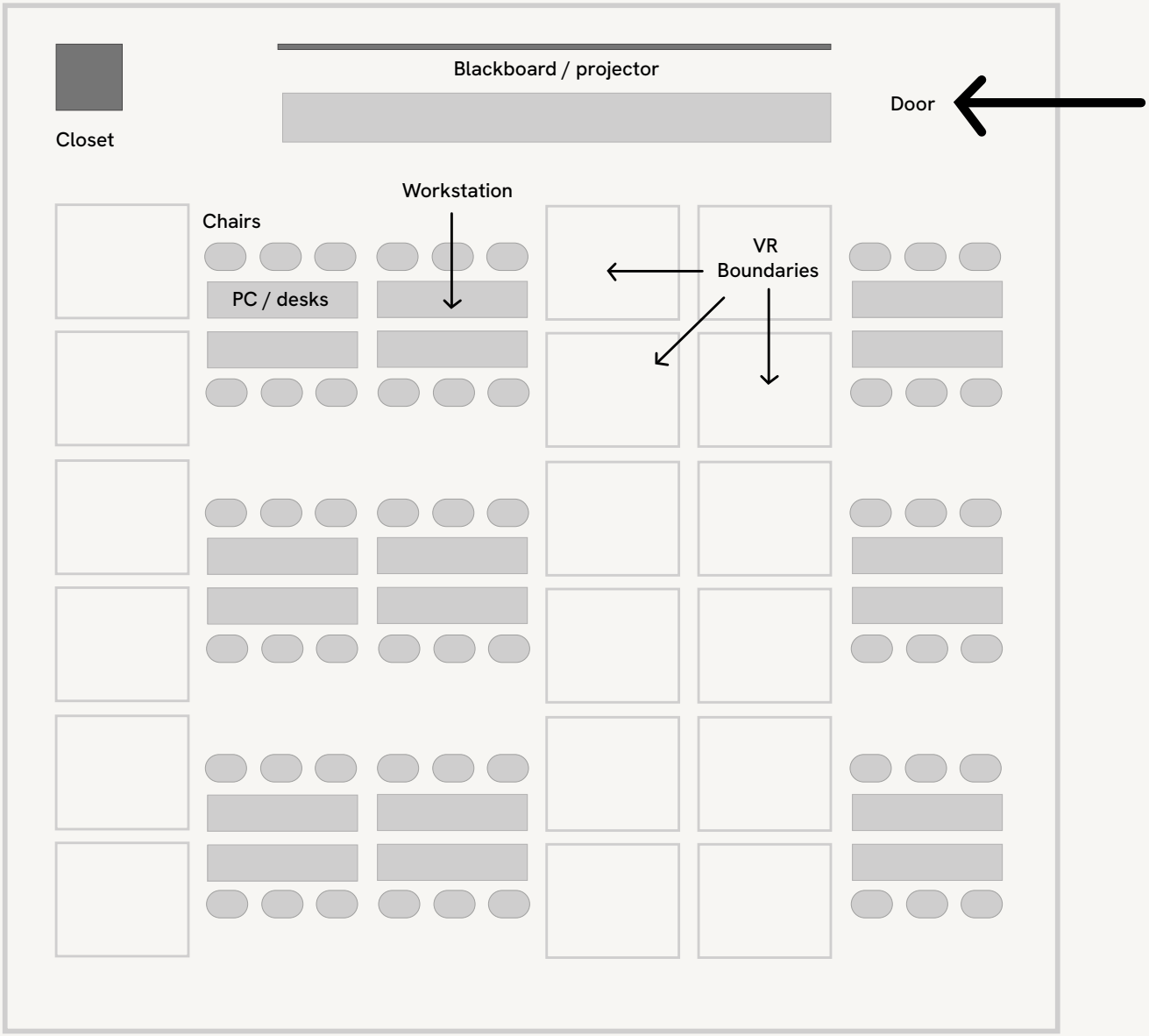
Graphics Card: Nvidia GeForce RTX 3070, 8GB, 3 DisplayPorts, HDMI (certified for Oculus VR experience)

Monitor: 27-inch Full HD (1080p) display, 1920 x 1080 @ 60Hz, IPS panel, 1000:1 contrast ratio, response time: 8ms (normal), 5ms (fast), HDMI and DisplayPort connections

The Meta Quest 2 headset (in that moment named Oculus Quest 2) was chosen due to its widespread availability and affordability; later, from empirical observation, it was still confirmed as a good choice due to its functional flexibility when using different VR applications, even if Meta still not have developed an educational modality. It is worth to note that the indications and information here given remain valid also after the choice done by the Politecnico, for other more recent ranges of HMDs, such as the Quest Pro or the Quest 3.

This device connects to the computer via a USB port and a DisplayPort using a five-meter cable, the Quest Link, useful as well to mirror PC-running application into an immersive point of view through the headset. The connection through cable is preferred to the wi-fi one due to its stability and fluentness in delivering content from PC to headset and vice versa. On the other side, using the Air Link connection through wi-fi will allow students and educators to have an enhancement into free of movement, and could reduce potential physical and infrastructure's damages. The choice in between the two connective systems has to rely on the typology of application, device and space involved.
Finally, navigation and engagement with VR content are facilitated through the two handheld controllers. ***(Fig. 3.1.2)***

▲ Fig. 3.1.2: Workstation, composed of the desk computer, the headset and the controllers.



▲ Scheme of the layout of the VR Laboratory at POLIMI university.

Risk & Contingency Map

TECHNICAL RISKS Headset updates, Wi-Fi contention, controller pairing, battery management	MITIGATION Frozen image of the scene on projector; Web viewer fallback; spare batteries; pre-class update window
HEALTH/SAFETY RISKS VRISE, collisions in small rooms	MITIGATION Prefer seated mode option, clear play-area markings, timeboxed sessions, ensure a safe “stop” protocoL
LEGAL/PRIVACY RISKS Data sources (HMD logs, voice/chat), lawful basis, retention	MITIGATION DPIA template, consent language, minimal data collection, retention schedule
ORGANIZATIONAL RISKS Staff load, booking conflicts	MITIGATION Intervention of facilitators, booking app, equipment inventory dashboard

3.2 VR-enhanced classes at POLIMI

Since the launch of the VR Laboratories in 2021, the dedicated rooms —L.0.4 at the Bovisa La Masa campus and 2.2.5 at the Leonardo campus— have been regularly booked and used by faculty from various departments. ***(Fig. 3.2a - 3.2b)***
Over time, a diverse range of courses have been delivered, with some instructors offering multiple courses within the same disciplinary area. Most participating departments are within the STEM and engineering fields.

From the first semester (September - January) of the academic year 2022/23 to the first semester (September - January) of the academic year 2024/2025, a total number of 2059 students have been involved in 152 lessons. Different department have been involved, in between Automation, Chemical, Energy, and Mechanical Engineering, Department of Electronics, Information and Bioengineering, Civil and Environmental Engineering, Department of Aerospace Science, Design, Architecture, Construction Engineering and the Built Environment.
In particular, faculty members from the Department of Chemistry have been highly active in using these spaces, conducting numerous practical exercises. Their sessions involve applications that simulate presence in virtual plants or laboratories (Simsci for Chemical Plants, or a self-designed app for the Test of a Radiochemistry Virtual Lab), where students access immersive environments via headsets and engage in hands-on activities.

Fig. 3.2a: VR Lab 2.2.5 in Leonardo campus.

Fig.3.2b: VR Lab L.0.4 in Bovisa La Masa campus.

3.3 Monitoring and evaluating tools

During the delivery of these years' VR lessons, several tools have been developed by METID task force team, to monitor the development of the project and to ensure a good quality of the educational methodology.

When delivering these typologies of lessons, it is important to collect feedback from students and

notes from the progress and preparation phase: these data can help the institution and trainers/ educators improving the quality of the VR lessons displaced. They are also very useful to build other monitoring tools, specifically designed for each educational situation if needed (other reports, tables, charts, etc.). What we have found interesting is the possibility to check the reports and the monitoring tools produced to overview the general progress of the semester or year, regarding the VR lessons.

3.3.1 Data collection through in-presence forms

In this section, details about the POLIMI in-presence forms are presented, to help other institutions build their own tables to be filled in by educators or trainers.
The goal of the form is to take notes about qualitative and quantitative elements of the specific lessons, from the number of students involved to the approach of the educational activities.
Here is an overview of what you can see in ***figure 3.3.1.***

In the first section, the following information is collected: the course title, the name(s) of the instructor(s) involved in the session, and the department(s) to which both the teaching staff and the course belong. The learning objectives of the session are also recorded. The start and end times of the session, the date of delivery, and any subsequent session dates (or frequency of use) are documented. The name of the METID team member responsible for recording the information is noted.

Data is gathered on the number of professors present during the session, the number of tutors, any external participants, the presence of technical staff, and any additional METID support staff. Student attendance is recorded, along with their seating arrangement—whether in groups or individually.

A subsequent section gathers information about the application used during the session: its name, the type of equipment required for operation, and a brief description of the software and its functions.
The language of instruction is also noted. The document continues with descriptions of the various stages of session delivery, including preparatory activities before classroom entry, the preliminary phase, the main session, and post-session activities.
It also details the classroom setup process, including who was responsible and how the preparation was carried out.
The final section includes special notes, the number of participants affected by VR sickness if any), and dedicated spaces for inserting links to Google Photos, the feedback questionnaire, and, eventually, to the final report.

CLASS TIME	
	VIRTUAL PROTOTYPING
INSTRUCTOR	PROFESSORS' NAMES
DEPARTMENT	MECHANICAL ENGINEERING (MASTER'S)
CLASS DATE	20/10/25
CLASS TIME	9:15 - 15:15
WRITER OF THE REPORT	WRITER'S NAME
NO. OF SPEAKERS	THE TEACHER JOINED THE MOST EXPERIMENTAL PART OF THE ELSSON
NO. OF EXTERNAL PARTICIPANTS	1
TECHNICIANS	TECHNICIANS' NAMES
METHODOLOGY SUPPORT	COLLEAGUE'S NAME
NO. OF STUDENTS	29+1 REMOTE
NO. OF WORKSTATION USED	15 (ALL)
STUDENT DIVISION	PAIRS OF SINGLES (13 PAIRS, 1 TRIPLET, 2 SINGLES)
SOFTWARE USED	UNITY AND UNREAL
NECESSARY EQUIPMENT	STUDENT'S PERSONAL LAPTOP, OCULUS AND CONTROLLERS, OCULUS LINK CABLE, GOOGLE CARDBOARD (ONLY THE TEACHER HAD IT AVAILABLE), STUDENT'S PERSONAL SMARTPHONE, USB STICK
SOFTWARE DESCRIPTION	IN UNITY, A 3D SCENE IS CREATED STARTING FROM A MODEL AND ADDING LIGHTS, CAMERAS AND OBJECTS. USING UNREAL ENGINE, THE PROJECT IS TRASNFORMED INTO AN APPLICATION THAT CAN BE RUN VIA SMARTPHONE OR VIA HMDs
LANGUAGE	ENGLISH
OUTCOME OF THE LABORATORY	STUDENTS SHOULD COMPLETE A SERIES OF ENVIRONMENTS DEVELOPED IN UNITY OR UNREAL AND DO SOME TESTING USING THEIR PEERS AS SUBJECTS OF THE EXPERIMENT

▲ Fig. 3.3.1: Example of the first part of the in-presence Form (Google Sheet)

3.3.2 Post-lesson Questionnaires

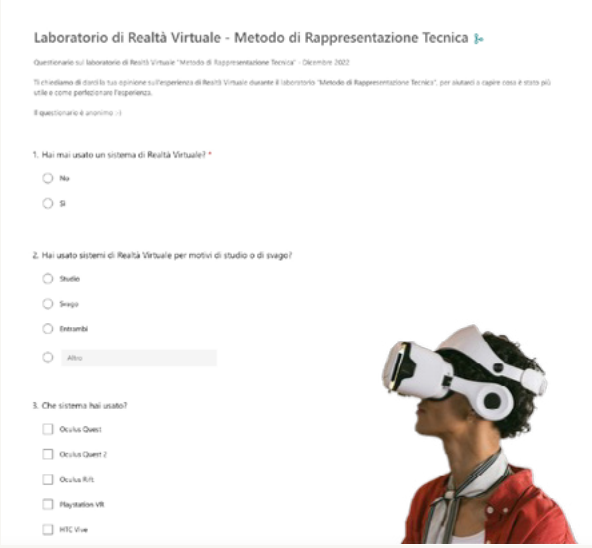
At the conclusion of the VR-based lesson, an online questionnaire is administered by the educators to the students. Its purpose is to collect general feedback on the use of VR technology, as well as data related to the lesson itself and students' perceptions of the innovative delivery method. Typically, the questionnaire is prepared using Microsoft Forms by the METID team and subsequently provided to course instructors in a customizable format. ***(Fig. 3.3.2)***

The initial section includes general questions regarding students' prior experience with VR technologies. These questions are optional and aim to assess the diffusion and familiarity of VR devices among the student population.
Following this, the questionnaire addresses students' experiences during the specific VR lesson, with a focus on any difficulties encountered. These questions are informed by prior METID team experience and observations gathered over time from various VR lesson implementations.
Subsequent sections ask students to rate, on a scale from 1 to 5, their level of appreciation for various new elements introduced in the lesson dynamics, such as instructional approach,technology, and content. The specific items evaluated vary depending on the nature of the lesson and the VR modality used.

Another item asks whether the activity was carried out individually or in a group. If group work occurred, a matrix question follows, prompting students to indicate, on a scale from 1 ("not at all") to 5 ("very much"), the perceived usefulness of collaboration with classmates during the activity.
The questionnaire continues with an open-ended question about the aspects of the session students most appreciated. Another open-ended question invites suggestions the respondent would like to offer to the instructor for improving the session.

The final item asks whether the student would like to see similar VR-based delivery systems applied to other courses. If the response is negative, the student is prompted to specify the reason. The questions and sections outlined above are designed to broadly address the various dimensions of student experience in VR-based lessons.

The questionnaire is intended to be adaptable by instructors or tutors to align with the specific context and pedagogical goals of each VR lesson, ensuring the collection of the most relevant feedback.



◀ Fig. 3.3.2: Screenshot of the first part of the Questionnaire (Microsoft Form)

https://forms.office.com/Pages/DesignPageV2.aspx?subpage=design&token=efcd7753489c45269e937158a1c1b2bc&id=K3EXCvNtXUKAjjCd8ope6zcfDdiDZHJArUaH6fMUZOhUNjlFSlUySVQ0REtMVU5OUFUyUUZQTFZBSy4u

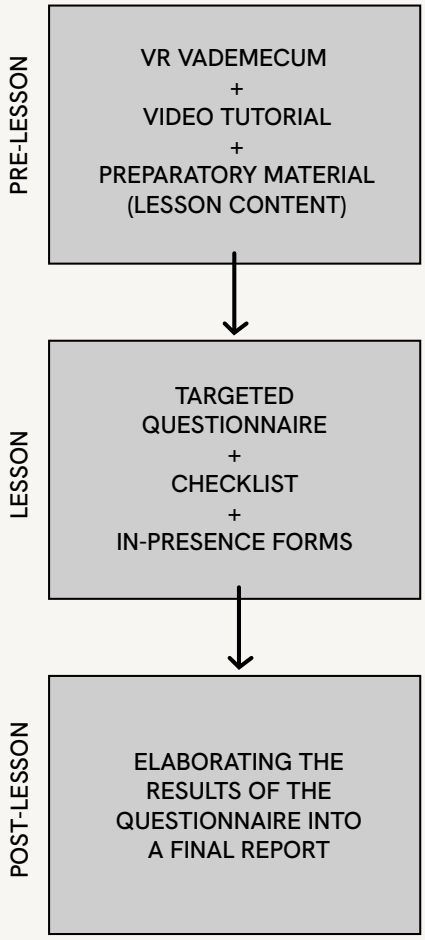
3.3.3 Final report

Once the questionnaire responses have been collected, they are analyzed and compiled into a document prepared by the METID team, referred to as the "VR Lesson Report."

This report includes the course title, the names of the instructors involved, and a descriptive overview of the course. The data obtained from the questionnaires are then presented in the form of graphical representations, accompanied by annotations and observations from both the instructor and the METID staff. The primary purpose of the report is to catalogue and present the collected data in a visually coherent and professionally formatted manner. The final report is then shared with the instructors who participated in the course delivery. ***(Fig. 3.3.3)***

▲ Fig. 3.3.3: Screenshot of a part of the Report tool (Google Doc)

Next chapter will focus on the guidelines for trainers, educators and students extrapolated from the empirical experience gained by METID task force during the development of the VR Labs.



◀ Ideal workflow use of the supporting and monitoring materials.

3.4 Supporting Research

Baldoni, V., Brambilla, F., Bruschi, F., Casiraghi, D., Denni, M., Marenghi, P., Longa, L., Pampanin, M., Pandocchi, S., Sancassani, S., & Santolini, B. (2024). Due anni di laboratori VR. Politecnico di Milano – METID Learning

Innovation. https://www.metid.polimi.it/pubblicazioni/

Galeazzi, A., Marenghi, P., Duò, L., Galardo, M., Rota, R., Sancassani, S., & Manenti, F. (2024). Virtual reality and digital twins for enhanced learning in chemical engineering. In Computer-aided chemical engineering/Computer aided chemical engineering (pp. 3535–3540). https://doi.org/10.1016/b978-0-443-28824-1.50590-1

04

Training materials for VR classes

This chapter reports the guidelines extrapolated from the empirical experience of **METID – Learning Innovation of Politecnico di Milano University** since the beginning of the VR Labs' development. To clarify the roles, METID works in the university realm as coordinator for the production and management of innovative learning and teaching methodologies and tools. From the observation of the VR Labs' activities, several guidelines have been formed both for educators and students. Different approaches, educational objectives and learning methodologies have been observed and merged into step-by-step suggestions.

4.1 Educators and Trainers Guidelines

Implementing VR in higher education requires careful planning and pedagogical competence.
The following guidelines, extrapolated from the empirical experience developed by METID, offer a structured, comprehensive approach to designing and conducting VR-based lessons, aiming to foster student engagement and effective learning.

It is worth to underline the instructional designer role of **METID - Learning Innovation**, to support educators and guide other colleagues in the structuring of the activities: when referring to the VR Labs already discussed in previous chapters, as underlined, METID works as facilitator in between instructors, students, technicians, providing instructional and methodological guidance and general support.

The guidelines given to the instructors are divided into eight logically sequenced steps:

1. Identifying Suitable Content for VR

Instructors should begin by knowing VR technology possibilities and assessing their course syllabus to pinpoint topics that would benefit from immersive learning. It is important to coordinate with the structure, inside each university, responsible for both the technical and methodological aspects.
This will help optimize time and effort in aligning the layout of the class, the structure such as software and hardware needed, and the educational objectives of the instructors.

2. Selecting or Developing a VR Application/Platform

Educators should next identify existing VR platforms aligned with the ILOs they want students to achieve. Here we talk about online virtual platforms –maybe already suitable as standard offers given by third agencies- or application that may be running in the computer or in the headset itself. Usually, it is preferred to let the application or platforms run into the computer, due to the highest graphic power of the inner components, then in the headset: this composition will need the headsets to be connected to the computer setting through the Link-cable or through Air Link, using the headset as a mirror of what the students can also see in the monitor.
On the other hand, despite being more limited in graphics, VR applications that run directly on headsets, can provide very good immersive experiences through other elements (playfulness, content quality, interaction, etc.). Additionally, there is also the advantage of making these applications much more practical to use in the classroom, due to the freedom of movement of the students.
There are several different typologies of applications, ranging from fitness to STEM ones. Depending on the educational objectives of the class, the most suitable one must be chosen –also considering license and price. If no suitable application exists, instructors may consult with internal or external developers to create one optimized for the specific headset in use.

3. Testing the Application

Before deployment, the VR application must be thoroughly tested for usability and technical reliability: instructors and eventual tutors must be conscious of the user flow in the application, to share it with the students and facilitate the lesson. Then, educators should also be aware of pain points inside the app, and the related solutions to the eventual problems.

4. Structuring the Lesson

The lesson should balance theoretical and practical elements, integrating VR meaningfully.
Students must be informed in advance about the session format, VR usage protocols, and the specific features of the application. We reported higher levels of secureness in performing tasks from students' point of view when they were aware priorly of the VR content displacement.

5. Organizing the VR Lab

Instructors should coordinate with methodologies and technical figures inside university to ensure equipment readiness, plan for student rotation in small groups – if needed, and provide on-site support to address technical or physical discomfort. On days or even weeks before the lesson it is worth discussing with these figures about lesson content and the idea of general layout. The coordination between these several roles should ensure a good starting point for the class.

6. Preparing Students

Usually, it is a good practice to share with the students some preparatory pre-lesson material designed from the structure managing the VR Lab. In the POLIMI university, METID had developed a PDF document (VR Vademecum) and a Video Tutorial –see next paragraphs- that can be shared with the students weeks before the lesson. Additionally, as already said, students should be briefed on the specific application used and expected behaviors in the VR environment.

Instructors should address issues related to motion sickness phenomenon, which may prevent some students from participating in the experiences. These students may feel excluded, and ideally, an alternative non-VR application should be available for them. Motion sickness may occur at different level, preventing students from positively experience the lesson: what is needed is to advice students of this possibility, and ask them to inform the supervisors (educators, tutors, etc.) if something discomfort occurs. To not make them feel embarrassed, it is important to remark how normal could it be to experience sickness. Usually, golden rules to prevent the phenomenon is to have open windows during the VR session, to enhance air circulation, and to reserve a space with chairs and water for eventual students in need.

7. Conducting the Lesson

Before the session, ensure the room is prepared with the support of technicians, ensure the equipment is functional, and the support staff is present. Depending on the booking flow of the university, it could be required to ask for support some days before the lesson.
Before the lesson, educators and tutors should check over the classroom, moving and changing the layout to provide a space free of obstacles and hazards, for the smoothest VR experience. Establish clear communication channels (e.g., hand signals, verbal cues) for students to indicate they need assistance. Prioritize the student's well-being. If a student removes the headset due to discomfort, assess their condition and provide support.
During the lesson, clearly communicate objectives, offer technical and emotional support, and provide an appropriate tutor-to-student ratio. It is a smart step to ask the students who have already used a system like that, and maybe pair students in order to balance the classroom's abilities. Educators and tutors should act as supervisors of the overall students' group, paying attention to their physical and emotional responses.

8. Collecting Feedback

After the session, gather student feedback to evaluate the learning experience, identify areas for improvement, and inform future VR initiatives. Maintaining a list of participants can facilitate follow-up communication and surveys.

◀ Lessons delivered inside the VR Labs (2.2.5 and L.0.4).

Comparing different VR experience set up

	DIRECTLY ON HMD	PC-TETHERED
STUDENTS PARTICIPATION	It depends on the application or platform used: if this allow a collaborative experience in between more users, HMDs will be used individually as device but the experience will be shared or activated in collaboration in between more students.	Mirroring the VR scenario into the PC desktop allows other students to participate (with different grades of participation) helping and informing their mates. Some VR application and platforms can be controlled by PC, with the headsets working only as an eye on the 3D environment.
PHYSICAL TRACKING	When wearing the headsets, tracking of students' eyes (and of what they see during the experience flow) it is not permitted. Mirroring the experience on the PC monitoris a golden rule. Apart from the view, body movement can be observed and monitored.	The experience given by PC gives the possibility to easily monitor eyes' movement and what the students are seeing in the environment. Body movement are difficult to be monitored.
LMS INTEGRATION	Both HMDs and PC-tethered modalities could allow the integration of LMS software and programmes,depending on licenses and add-in programmes.	Both HMDs and PC-tethered modalities could allow the integration of LMS software and programmes,depending on licenses and add-in programmes.
ORGANIZATIONAL	When using HMDs, it is good to have an expert role inside the team organizing and managing the activity (in a pre, during and post phase) HMDs could present problems related to the hardware and software, and these problems not always can be predictable.	Giving the VR experience through PC may report less problems related to the use of the device: they are more used in between technicians, and finding a supporting role in a pre, during and post phase may be easier than with HMDs. Theheadsets are use only as a mirror.

ORGANIZATIONAL	When using HMDs, it is good to have an expert role inside the team organizing and managing the activity (in a pre, during and post phase) HMDs could present problems related to the hardware and software, and these problems not always can be predictable.	Giving the VR experience through PC may report less problems related to the use of the device: they are more used in between technicians, and finding a supporting role in a pre, during and post phase may be easier than with HMDs. Theheadsets are use only as a mirror.
INFRASTRUCTURES, DEVICES, TOOLS	Depending on the connectivity system chosen, HMDs could need a link cable with the PC. They need as well batteries for the controllers, and it may be useful to have some cleaning tool for the end of the lesson. Charging bases or alimentation cables are needed to charge the HMDs. These devices has to be used in a safe zone, outlining specific area for the HMD called "boundaries" (they may be created with tape on the ground, or other methods). Usually they should be supported by a workstation comprehending as well a PC with monitor, mouse and keyboard.	The infrastructure, in both situations, is the same: the PC workstation are associated with a specific area in which HMDs will be used (boundaries). They will need as well a monitor, keyboard, mouse, etc.
PHYSICAL TRACKING	When using the HMDs, students, depending on the experience programmed, may have more freedom of movement and interaction -always considering safe area to perform in. This freedom permits the experience to be organized in different spaces and rooms. HMDs can be used also in a stationary modality.	Tethering from PC doesn't allow the student to have different grades of movement. The use of PC software and hardware features permits to run heavier applications and programmes with an higher speed. Usually, it allows as well more students to participate due to the direct mirror on the monitor.

4.2 Students Guidelines

The educational path involving VR requires a mindful and proactive approach from students, both in terms of the innovative methods of in-class engagement and in avoiding the risk of reducing the experience to mere entertainment, thereby losing sight of the ILOs.

Indeed, students must be prepared to what they will face in the class, both from the technological and the methodological point of view. It may be not every one of them has ever experienced a VR installation or application, thus resulting in confusion and overcome of the emotional and ludic part over the rational learning-oriented mental approach.

VR Vademecum

This is the reason METID has developed during the year a VR Vademecum PDF document, with the aims to offer a clear understanding of the available tools and to enhance students' familiarity with the functioning of VR Labs. **(Fig. 4.2a)**
In doing so, it seeks to foster a more rewarding and productive learning experience.
The Vademecum must be shared from the educators to the students prior to the lesson: professors should ask the students to read it to better prepare for the learning experience.

Main contents of the document:

- **What are the VR Labs they are entering;**
- **What are the tools they are going to use;**
- **How to wear and generally use the headsets and the controllers;**
- **Some words on the VR sickness phenomenon and how to manage it.**

Fig. 4.2a: Cover of the VR Vademecum for the students)

Video tutorial

Additionally, the main practical steps required prior to entering the Labs (such as Labs' rules, description of the spaces, of the tools, etc.) are presented through a video, to facilitate a smooth introduction to the VR learning environment. The video should be shared from educators to students prior to the lesson as well, or projected in the classroom itself before the start of the lesson. Inside the video:

- **A very first introduction to the Labs, and the request to follow educators and trainers' indication for the delivery of the lesson;**

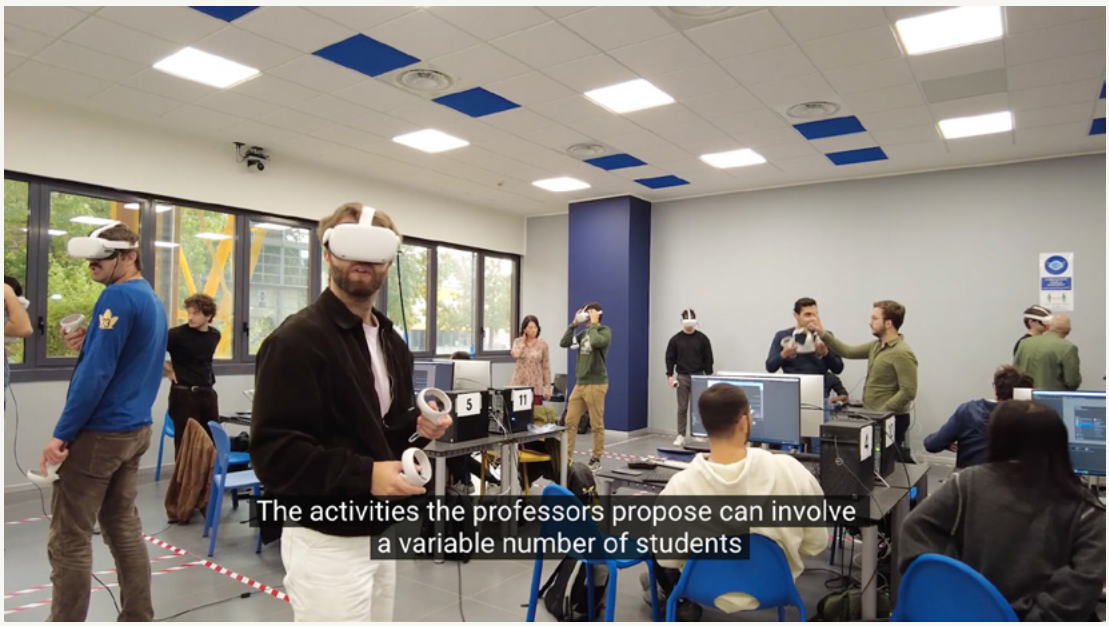
- **The composition of the workstation, from the desk computers to the headsets and the other tools involved;**

- **The dedicated working area, corresponding to the boundaries of the headsets, where the VR content will be safely displaced. As seen in the screenshot, in the Labs these area are given by tape on the ground;**

- **Different parts and controls of the headsets, and the general functioning of the controllers;**

- **How to safely wear the headsets;**

- **The need for a collaborative environment when the lesson involves more students than the number of workstations: one student will experience the VR content, the others will help with the tools and the PC functioning;**



- **Few words for the VR sickness, and how to manage it if happening.**

4.3 Shared Materials

To ensure a smooth managing flow in between stakeholders involved in the different roles for the organization of the VR classes, we suggest considering to share some of the materials previously explained.
The materials shared among all stakeholders —including, when necessary, directly involved members of the teaching staff—enable a clear understanding of the current status of classrooms designated for VR-based instruction. This information exchange encompasses not only the operational status and maintenance of the devices used, but also the various applications and services that have been employed in past lessons.

Moreover, it includes an analysis of the pedagogical methods adopted by instructors during VR sessions.
For example, at POLIMI, we usually share In-presence Forms via the platform Slite, commonly used by the METID Task Force. Specific pages are created within the platform according to the type of material to be shared, and access is granted to relevant stakeholders (technicians, educators, informatic services).
Among the materials shared are also the individual lesson reports, extrapolated from the in-presence form (practically a Google Doc) which provide a detailed account of each VR session.

Additionally, technical maintenance sheets concerning the VR devices are shared. A document is compiled with updates or modifications related to the devices, along with a description of the maintenance activities carried out. Ideally, such maintenance should occur on a monthly basis, given the potential for technical issues due to wear and tear or depleted batteries, as well as the frequent updates of headsets and app.

The recommended checklist for maintenance activities includes the following steps:

- **Verification of the presence of all equipment at each station;**
- **Functionality and eventual presence of the app on the PC station;**
- **Checking the accuracy of headset's boundaries settings;**
- **Ensuring the correct user account is logged in;**
- **Verifying the headset's internet connection;**
- **Testing at least one application,** with any issues noted—if a specific app is needed during the maintenance period for instructional or experimental purposes, it should be downloaded;
- **Testing of audio and haptic feedback;**
- **Verification of the virtual environment;**
- **Updating the software to the latest version**, completing any required updates (including checking via browser), and restarting the system to ensure full functionality;
- **Checking the charge status of headsets** and controller batteries and taking action where necessary.

In addition to the Maintenance Sheets and VR Lesson Reports, a Slite page is maintained listing the contact information—either direct or indirect, depending on availability—of the various stakeholders involved, in case specific individuals need to be reached, and the needed passwords.

Starter Kit

Here you can find the link to a list of reusable template:

Decision Matrix "Should we use VR here?"

FAC SIMILE_In-presence form – the template for the Google Sheet in-presence form used at POLIMI for monitoring the number of students, tutors, educators, software used, modalities, development of the lesson and so on

FAC SIMILE_Overview of VR Lesson – this Google Sheet file is useful to collect all the data from the different lessons taken inside the VR Labs, and put them in an unique file to overview the Labs during time

Vademecum for Students – the PDF file of the previously cited Vademecum developed for the students, to give them prior information and knowledge about the technology and the laboratories: this could be inspirational for the development of specific Vademecum for the single case in universities

VR sketching template - useful in VR design phase, to interact with VR expert, to define spatial position, sequence, motion and interaction when visualizing objects in VR and narrating users' actions

VR course syllabus template – an example of course syllabus in which a VR activity is integrated

VR lesson implementation checklist – to recall all step of design and implementation process

VR lesson Pre-brief and debrief checklist – to recall all activities and actions that is important to implement to conduct and effective VR session

Rubric template - to assess the 3 domains of knowledge

Simulator Sickness Questionnaire (SSQ) – to evaluate the VR experience in terms of wellness

System Usability Scale (SUS) – to assess the usability of VR

Virtual Reality Neuroscience Questionnaire (VRNQ) – to evaluate four different key area of VR experience

Reflection grid – student worksheet to actively reflect on experience

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