Electronic, didactic and innovative platform for learning based on multimedia assets

e-DIPLOMA

Funded by the European Union

6.3: Policy recommendation 2

Strategic Policy Recommendations for Integrating VR/XR and AI in Education: A Comprehensive Framework for Adopting Disruptive Technologies at European, National, and Local Levels

Version 1.4

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*This document is available in **English** and in the seven national partner languages: **Bulgarian, Dutch, Estonian, Greek , Hungarian, Italian, and Spanish**.*
The translated versions can be found in the dedicated section of the project's official website. To access them, click HERE

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2. Table of contents

3. Introduction

3.1 Executive Summary

This deliverable, *D6.3 – Policy Recommendation 2*, represents the second and final policy recommendation report developed within Work Package 6 (Policy Recommendation) of the e-DIPLOMA project.
It provides an integrated framework of strategic policy directions for the adoption of Virtual Reality (VR), Extended Reality (XR), and Artificial Intelligence (AI) in education across European, national, and local levels.

Informed by the project's empirical results, this document articulates a set of evidence-based, multilevel recommendations aimed at assisting decision-makers in advancing educational, technological, and policy frameworks.

The deliverable synthesizes:

- research-based insights from previous e-DIPLOMA reports;
- participatory policy inputs collected from stakeholders;
- ethical and social principles for responsible digital innovation;
- and alignment with the EU's strategic framework for digital transformation in education.

The overarching objective is to guide the inclusive, ethical, and effective integration of disruptive technologies in education, reinforcing the European vision of a human-centered digital learning ecosystem.

3.2 Relation to other project documents

This deliverable builds directly upon, and complements, several earlier e-DIPLOMA outputs:

D2.1 – Best practice report

D2.2 – Review of e-learning eco-system

D.3.5 – Testing and Piloting Conclusion report

D5.1 – Competency Specifications

D5.2 – Definition of appropriate metrics for the assessment of learning competencies

D5.3 – System usability and validation report and ergonomics of evaluation measures

D.5.4 –Specifications Report

D.5.5 – Social and educational impact report

D6.1 – Preliminary Policy Recommendations

D6.2 – Report on the SWOT

D7.2 – Ethics Plan

D.7.3 – Sociocultural Contextualization Policy

D.7.4 – Report on ethics screening and overall legal compliance

Together, these documents ensure continuity and coherence in how evidence, experimentation, and stakeholder engagement inform the final policy recommendations presented here.

3.3 Abbreviation List

AI	Artificial Intelligence
AR	Augmented Reality
XR	Extended Reality
VR	Virtual Reality
MR	Mixed Reality
EU	European Union
EC	European Commission
REA	Research Executive Agency
OECD	Organisation for Economic Co-operation and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
WP	Work Package
T	Task
HEI	Higher Education Institution
GDPR	General Data Protection Regulation
DEAP	Digital Education Action Plan
EHEA	European Higher Education Area
ECTS	European Credit Transfer and Accumulation System

CAMIL	Cognitive Affective Model of Immersive Learning
ELT	Experiential Learning Theory
ICT	Information and Communication Technology
MoE	Ministry of Education
MoU	Memorandum of Understanding
KPI	Key Performance Indicator
D	Deliverable
VET	Vocational Education and Training
AIED	Artificial Intelligence in Education
STEM	Science, Technology, Engineering and Mathematics
SDG	Sustainable Development Goals
R&I	Research and Innovation
HORIZON	Horizon Europe Programme
LMS	Learning Management System
DE	Digital Education
DIGCOMP	Digital Competence Framework for Citizens
UGC	User Generated Content
QA	Quality Assurance
PM	Project Manager
Co-Design	Collaborative Design
ToC	Theory of Change

3.4 Reference Documents

See References Section included in this document (page 130)

Context

1.1 Disruption of context in post-COVID-19 educational challenges

The COVID-19 pandemic has accelerated an unprecedented shift in the education system across the entire world. Well-established conventional education with traditional teaching methods, tested and elaborated programs, and familiar learning environments faced an extraordinary challenge not experienced by educational systems on this level in decades. Previous research shows that while schools and training providers moved rapidly to remote formats, the limits of conventional e-learning platforms became strikingly obvious. This emergency exposed fundamental weaknesses in digital preparedness and exacerbated pre-existing inequalities. Although the process of digitalization had been developing before the pandemic crisis, it rapidly became explicit that European educational infrastructure and research on the matter were dragging behind and needed urgent actions. Hundreds of millions of students at all levels have been affected by the COVID-19 educational disruption (UNESCO, 2020), resulting in an abrupt and largely unplanned transition to digital learning environments.

The health crisis forced education systems into an abrupt transition to remote teaching, generating what can be described as a “context disruption.” This disruption was not limited to the medium of delivery; it fractured the very conditions in which teaching and learning normally occur. There has been multiple evidence of familiar patterns of social interaction, shared spaces, and structured experiences collapsing dramatically fast and in an unpredictable manner. For teacher education, as for many other critical social fields, this led to severe consequences, such as weakened social bonds, difficulties in sustaining meaningful reflection, the loss of practice-oriented learning, and a sudden overburdening of educators on every level who were forced to embrace unfamiliar complex roles, as they had to become moderators, instructional designers, and technical support, sometimes all at once. The pandemic also revealed deep digital inequalities, both in access to infrastructure, technologies, software and in levels of digital literacy. The situation was exacerbated by the fact that certain pedagogical practices often remained at the level of emergency improvisation rather than deliberate instructional design.

Passive learning modes often characterized digital education during the health crisis. Such models were typically over reliant on video lectures, as well as downloadable worksheets and static content, while failing to support the cognitive, affective, and embodied dimensions of learning. As these aspects of education are essential for deep and durable knowledge acquisition, their absence heavily affected all sides of the educational process, from educators to students, to their parents, to institutions. Many countries in the European Union and across the world were struggling to adopt emergency solutions to the unprecedented challenge, among which were learning management systems and student information systems. The crisis unveiled the fragility and inflexibility of education systems. Remote learning reliability varied dramatically depending on national, regional, and personal contexts, and many actors lacked coherent digital education ecosystems. That was all despite the rapid deployment of online education modalities (OECD, 2023). The OECD investigation also confirms that specific remote learning strategies neglect interaction, feedback, embodiment of education, and personalization, which are crucial for effective learning, especially for more vulnerable students.

Access to technology, digital literacy, human interaction, and learning support were central among the disparities revealed by that crisis. It was also discovered, for instance, that students from specific socio-economically disadvantaged backgrounds were more likely to face connectivity issues. Many of them lacked access to appropriate learning devices and often experienced limited parental support. According to the World Bank (2022), this has intensified already existing achievement gaps between learners experiencing socio-economic disparity. Under these conditions, educators were forced to adapt pedagogical practices to instruments that initially were barely designed for collaborative and practice-based instruction processes. Many of them, unfortunately, faced severe professional and psychological burnout. Some educators even reported the feeling of disempowerment. Insufficient institutional support seemed to exacerbate the situation.

The current data shows that students might experience declining motivation and that their feelings of isolation increase. This scenario is particularly strong in the circumstances when e-learning is presented by viewing pre-recorded videos or submitting assignments on an online platform, which was the most widespread approach, specifically at the earlier stages of coping with the crisis. These systemic issues show the urgent need to move beyond the emergency remote education approach. This project argues that more resilient, inclusive, and human-centered digital learning ecosystems could be the solution. There is no surprise that international organizations increasingly call for hybrid models that combine the flexibility of digital delivery with pedagogical depth and meaningful human interactions among all contributors to the educational process.

The pandemic is believed to have disrupted educational processes temporarily. In addition, it revealed structural limitations in how digital education has been conceived and implemented. It also proved that meaningful online learning must integrate social-emotional engagement, experimental learning, ethical considerations, and certain technological advancements. It appears that the new educational tools might help rebuild social connections between learners, make studying feel more engaging, and even ease the pressure on teachers. For the European Union, this seems less like a fleeting experiment and more like a chance to turn disruption into a promising, longer-lasting technological and social development. The real hardship, though, is how to use technology to reshape the conditions of learning. This project seeks to demonstrate that the new opportunities should not be about restoring what was lost but about moving toward a system that proves to perform in a more inclusive manner and be better prepared for the future challenges and abruptness. These lessons form the basis for projects like e-DIPLOMA, as they aim to reimagine digital education through immersive technologies, through co-designed and pedagogically aligned innovation. Building on this reflection, the following section outlines the methodological foundation through which the e-DIPLOMA project has developed its evidence and translated it into policy-oriented insights. It explains how research, pilot experimentation, and stakeholder collaboration were combined to transform the project's vision into a coherent set of strategic recommendations.

Methodological Design

The preparation of this report was guided by a structured methodology designed to ensure that its policy recommendations are credible, evidence-based, and fully aligned with European strategic priorities in digital education. This section outlines the analytical process through which the project's materials and results were reviewed, interpreted, and transformed into coherent policy guidance. The methodology combined **documentary research, internal analysis of project deliverables, and**

participatory reflection with stakeholders, thus creating a transparent chain from data collection to policy formulation.

The work began with a **desk literature review** aimed at framing the e-DIPLOMA results within the broader European and international context. This review covered major policy documents such as the Digital Education Action Plan (2021–2027), the European Skills Agenda, the Artificial Intelligence Act, and the European Education Area strategy, as well as key reports from UNESCO (Global Education Monitoring Report 2020) and the OECD Digital Education Outlook 2023. The purpose of this phase was to understand how the current European policy environment defines priorities and challenges in digital transformation, and to identify the gaps that the project's findings could help to address. The desk review thus provided the conceptual and political grounding for interpreting the evidence collected within the consortium.

Building on this foundation, the authors examined the **results and documentation produced in Work Package 2**. This material offered a detailed mapping of the European ecosystem for XR and AI in education, highlighting emerging good practices, systemic barriers, and conditions that enable successful innovation. The analysis of WP2 allowed the authors to identify which institutional and pedagogical models are most relevant for policy transfer, and to understand the broader structural dynamics that influence the adoption of new technologies across educational systems. These insights became the baseline for contextualizing the recommendations and for defining the main policy domains addressed later in the report.

The next step focused on the analysis of the **evidence produced under Work Package 5**, which provided the empirical dimension of the project. The WP5 documentation contained the results of **pilot activities** testing immersive and AI-supported learning environments across several countries. The authors reviewed these materials not in technical terms, but as a source of practical lessons on how immersive tools affect learning, motivation, and inclusion. The pilots demonstrated that technology can be effective when embedded in coherent pedagogical frameworks and supported by appropriate infrastructure and teacher training. The review of WP5 thus helped to identify under which institutional and pedagogical conditions XR and AI generate real educational value and how these insights could translate into operational policy measures.

The analysis of the **brainstorming sessions conducted under Work Package 6** followed a qualitative and inductive approach aimed at transforming stakeholder input into actionable policy insights. All proposals and comments collected during the 6-5-3 collaborative sessions were first organized in a shared database and then systematically examined using **qualitative coding techniques**. Each entry was read and classified according to its thematic focus — for example, *teacher training, AI ethics, inclusion, XR integration, funding, or infrastructure* — and its **level of policy intervention** (*European, national, or local*). This process made it possible to identify recurrent issues and patterns across participants with different professional backgrounds and levels of influence.

The coded data were subsequently grouped into broader **policy areas**, which provided the analytical backbone for structuring the recommendations. Frequency counts were used to determine which themes were most frequently raised, indicating areas of shared concern among stakeholders. This thematic synthesis allowed the team to move from individual suggestions to aggregated policy orientations, highlighting both strategic priorities and operational measures.

The emergent policy areas were cross-checked against the findings from WP2 (ecosystem and best practices) and WP5 (pilot and prototype outcomes) to ensure **internal coherence and empirical validation**. Through this iterative triangulation, the project team distilled a set of evidence-based, multilevel policy recommendations that reflect both the diversity of stakeholder perspectives and the concrete needs of the European education sector.

The preparation of policy recommendations was also informed by the ethical framework established under Work Package 7, ensuring that the entire process followed the highest standards of integrity, transparency, and social responsibility. The *Ethics Plan (D7.2)* provided the methodological foundation for integrating ethical principles into both data analysis and policy formulation. This included adherence to EU and international legislation, such as the *Charter of Fundamental Rights of the European Union*, the *European Convention on Human Rights*, the *General Data Protection Regulation (GDPR)*, and the *European Code of Conduct for Research Integrity*.

All analytical and consultative activities were conducted in line with the project's "do no harm" principle and with strict respect for participants' privacy, dignity, and informed consent. The process also benefited from continuous monitoring by the project's External Ethics Advisor and the internal Ethics Committee, which ensured compliance with ethical standards and reviewed any potential issues related to human participation, data handling, and artificial intelligence.

The ethical dimension was particularly relevant in the context of AI and data-driven education policies. In line with the safeguards outlined in WP7, particular attention was given to preventing bias, ensuring diversity and inclusion, and promoting the use of AI systems that are transparent, accountable, and human-centric. These ethical commitments directly shaped the way stakeholder input was interpreted and translated into recommendations: for example, proposals related to AI governance, data privacy, and inclusion were systematically cross-checked against the principles of fairness, non-discrimination, and gender equality defined in the *Ethics Plan*.

Consequently, the policy recommendations emerging from this report are not only evidence-based and participatory but also ethically sound. They aim to support the development of educational technologies that are equitable, trustworthy, and aligned with the broader societal and environmental well-being goals promoted by the European Union.

The final drafting phase integrated insights from all these components. The desk review provided the strategic alignment, the analysis of WP2 and WP5 contributed empirical and structural evidence, and the interpretation of WP6 materials added participatory validation and policy relevance. Through this cumulative process, the e-DIPLOMA results were transformed from project outputs into actionable policy guidance. The methodology therefore guarantees that the recommendations presented in this document are not descriptive summaries but operational instruments—rooted in evidence, tested through experience, and co-shaped with the actors who will ultimately implement them.

Definition and the role of disruptive technologies in transforming education

Clayton Christensen, a renowned American academic and businessman, first introduced the 'disruptive innovation', the cornerstone term for understanding technological innovations' transformative potential in The Innovator's Dilemma (1997). According to Christensen, what may appear at first as a marginal development can, over time, fundamentally alter an entire system. And educational sphere is not an exception from this tendency. The global shift during the COVID-19 pandemic made it almost impossible to ignore the role of such technologies, as digital platforms moved from being auxiliary instrument to the backbone of teaching and learning. The experience acquired from the health crisis may suggest that disruption in education in modern conditions is less a temporary adjustment and more an ongoing transformation.

Christensen drew a now well-known distinction between two kinds of technological change: sustaining and disruptive. Sustaining technologies, in his view, build incrementally on what is already in place, accepted and widespread. For instance, it can be a new projector taking the place of a chalkboard, or a learning management system quietly reinforcing conventional classroom routines. Disruption, however, follows a different logic. It often begins in imperfect forms that appeal to a small subset of potential users, but over time, these cumbersome beginnings can unsettle entire systems.

Examples of Disruptive Technologies in Education

- E-learning platforms: a virtual environment that enables the management and access to online educational resources.

- Mobile learning (mLearning): an education process through smartphones and portable devices.

- Google's ecosystem (Classroom, Meet, Docs, Forms, Scholar).

- Massive Open Online Courses (MOOCs): free online courses available for anyone to enroll, often provided by leading educational institutions.

- Learning Management Systems (LMS) such as Moodle, and collaborative tools like Piazza and Edmodo. These tools are interactive and community-based virtual classrooms.

- Gamified platforms (Quizizz, Kahoot, Prezi): innovative assessment and participation as interactive experiences.

This variety of tools demonstrates that disruptive technologies are no longer solely supportive instruments. They are a central part of the teaching and learning structure.

This report focuses on particular types of disruptive technologies in education - Virtual Reality (VR), Extended Reality (XR), and Artificial Intelligence (AI) (Table 1). Each offers something different, and together they seem to offer new ways to address the long-standing frustrations with conventional e-learning. The interest in these types of technologies is dictated by the fact that they have emerged as potential catalysts for educational transformation. Unlike traditional digital instruments, these technologies introduce fundamentally new modalities of interaction, immersion, communication, and personalization. And first and foremost, it is critical for this report to define these new phenomena to ensure clarity in the following analysis and consecutive policy recommendations.

The term 'disruptive technologies' refers to innovations that fundamentally change or shift established practices. This presents new possibilities that eventually redefine norms and standards within a particular field. In education, disruptive technologies do not merely bring digitalization into the existing classroom practices. Instead, they reform the architecture of teaching and learning processes, from how knowledge is accessed and constructed to how learners interact with content, with other learners, and with instructors.

Virtual and Extended Reality (VR/XR)

Virtual Reality (VR) usually refers to three-dimensional immersive environments, which are defined as the use of computer modeling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment. It is presented in digital spaces that learners can move through using headsets, gloves, body suits, or other sensory gear. In a typical VR format, a user wearing a helmet with a stereoscopic screen views animated images of a simulated environment (Lowood, 2025). Extended reality (XR) is an emerging umbrella term for all immersive technologies, including virtual reality, augmented reality, and mixed reality. Augmented Reality is defined in this project as digital overlays (text, images, sound, videos, or 3D models) on the physical world. Mixed Reality is an immersive technologies that bring physical objects into digital environments or digital objects into physical reality (European Data Protection Supervisor, 2023), which is basically blending physical and virtual elements. These technologies can promote embodied and situated learning. With the help of these instruments, learners can manipulate, observe, experiment, and create with digital representations in ways that mirror real-world experiences.

The e-DIPLOMA project positions VR and XR as potential solutions to some of the limitations of traditional online education. That is because it appears that immersive technologies allow learners of all ages to recreate simulations of laboratories, fieldwork, workplaces, historical events, or environments, where they can engage in practice-based learning. This shift enables cognitive processes to be supported by sensorimotor interactions through fostering deeper motivation and transfer of knowledge to real-life contexts.

Such immersive experiences can be rather democratizing than discriminating. Students from remote regions or those with financially disadvantaged backgrounds may gain access to experiences otherwise inaccessible to them and thus overcome disadvantages and disparities. However, it is critical to realize that this positive potential is not guaranteed at all, because meaningful integration of new technologies requires investment in various fields, such as technological infrastructure and educators' training.

The project emphasizes that VR/XR technologies demonstrate promise in domains such as STEM and vocational education, where embodied interaction and spatial reasoning play a central role. These tools may also accommodate heterogeneous learning preferences by providing multiple forms of engagement and input. At the same time, significant challenges remain. The cost of hardware is considerable, quality benchmarks and usage protocols are still evolving, and not all learners may feel comfortable adopting such approaches. For these reasons, the implementation of VR/XR requires careful planning rather than uncritical enthusiasm.

Artificial Intelligence (AI)

Artificial Intelligence in education refers to computational systems that can analyze data and make autonomous decisions. This new instrument creates prospects for improving teaching and learning. However, it is important to remember that despite continuing advances in computer processing speed and memory capacity, there are yet no programs that can match full human flexibility over wider domains or in tasks requiring much everyday knowledge (Copeland, 2025). Adaptive learning platforms, automated feedback tools, as well as tutoring systems are normally included in AI educational applications.

The e-DIPLOMA project highlights AI's transformative potential in promoting personalized learning strategies. In such circumstances, instructional content and pacing adapt to each learner's needs and challenges while recognizing and conforming to progress. Through constant data collection and analysis, AI can provide real-time formative feedback. The latter is crucial for the educational activities and is significantly underrepresented in conventional digital education, based on recorded video lectures and online assignments in the form of tests, multiple choice or texts. It can also support inclusive education by offering multilingual interfaces, which is crucial for supporting diversity and multicultural integration, speech-to-text tools, which promotes inclusivity, or content personalization based on cognitive or sensory profiles, which appears to be especially crucial for students who struggle to work autonomously or need additional support from their institution or instructors.

Moreover, AI can aid the evaluation of competency-based learning by collecting and analyzing diverse forms of evidence, such as interaction logs (how often a student interacts with course material and how long s/he spends on accomplishing the task) to gesture tracking (for instance, hand tracking for doctors or engineers), or to affective responses (tracking signs of frustration, anxiety, confidence, etc.). This supports the shift from static, summative testing, when a final exam focuses only on a "snapshot" of a student's knowledge, towards more holistic and continuous assessment, as it is advocated by e-DIPLOMA's framework for XR/AI environments.

Nevertheless, it is also critical to emphasize, that this project is informed by the fact that AI is not a completely neutral tool. There is previous evidence that its integration into education requires careful consideration of ethical implications, such as data privacy, algorithmic bias, and the risk of replacing human pedagogical judgment with opaque digital decision-making systems. That is the reason why the project is seeking the need for transparent and human-centered AI. For this cause, it is developed and deployed within clear governance structures that prioritize learner well-being and pedagogical coherence.

Table 1. Disruptive Technologies in Education: VR/XR and AI

Technology	Definition	Key Educational Applications	Potential Benefits	Main Challenges
Virtual & Extended Reality (VR/XR)	VR: computer-generated 3D environments enabling immersive interaction via headsets, gloves, suits,	Simulations of labs, fieldwork, workplaces, historical events; practice-based and situated learning; especially relevant for STEM and	- Supports embodied and situated learning through sensorimotor interaction. - Promotes motivation and transfer of	- High hardware costs. - Lack of stable quality standards and usage protocols. - Risk of uneven accessibility if infrastructure and

	etc. XR: umbrella term covering VR, AR (digital overlays on physical world), and MR (blending physical and virtual elements).	vocational education.	knowledge to real-life contexts. - Expands access for learners from remote or disadvantaged backgrounds. - Offers diverse modes of engagement, accommodating heterogeneous learning preferences.	teacher training are insufficient. - Not all learners may feel comfortable adopting immersive formats.
Artificial Intelligence (AI)	Computational systems that analyze data and make autonomous or semi-autonomous decisions; includes adaptive platforms, automated feedback, and tutoring systems.	Personalized learning strategies; adaptive pacing and content; multilingual interfaces; speech-to-text tools; competency-based assessment via interaction logs, gesture tracking, and affective response analysis.	- Enables real-time formative feedback, often missing in traditional e-learning. - Facilitates inclusivity (multilingualism, accessibility tools). - Enhances personalization for diverse learner profiles. - Supports shift toward continuous, holistic assessment.	- Current AI cannot replicate full human flexibility or everyday reasoning. - Ethical concerns: privacy, algorithmic bias, and reduced transparency. - Risk of undermining human pedagogical judgment. - Requires clear governance structures and human-centered integration.

<u>The Transformative Potential in Education for VR/XR/AI</u>

When they are combined, VR/XR and AI instruments have the potential to create intelligent, immersive learning ecosystems that produce interactive, adaptive, accessible, and context-sensitive environments. They make possible:

- To redesign curricula around competencies that reflect real-world complexity,
- To expand access to high-quality experiential learning regardless of location,
- To support education with data-informed insights and tools,
- To foster learner agency through personalized, inquiry-driven approaches.

What is very important, it is safe to say that disruptive technologies are not inherently beneficial. Their transformative power depends entirely on how they are embedded within pedagogical and institutional practices. The e-DIPLOMA project makes clear that technology must follow pedagogy, and not the other way around; therefore, tools should serve clearly defined learning purposes, and reflect shared educational values, such as autonomy, sustainability, inclusion, accessibility, and co-development.

From this point of view, the project suggests that VR/XR/ and AI are best understood not simply as tools to be deployed, but rather as mediums through which new forms of learning institutions and practices can emerge. Some perspectives can challenge educators, learners, and policymakers to rethink what counts as knowledge, how it can be constructed, and what forms of interaction might be the best to support its acquisition in a digitally saturated world.

Theoretical Foundations for Immersive and Disruptive Technologies in Education and Concerns That They Raise

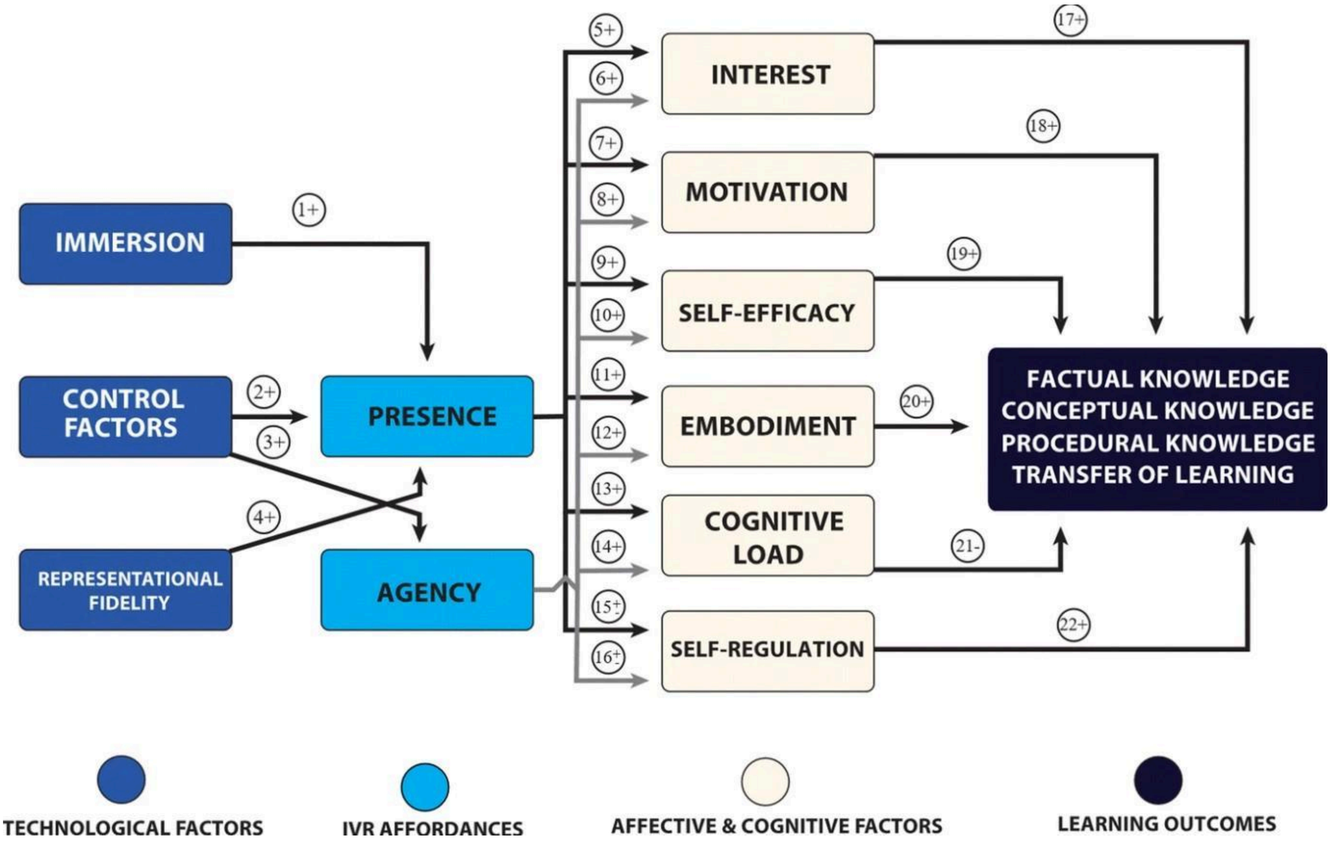
This chapter explores theoretical foundations for the use of immersive and disruptive technologies in education, examining the potential of immersive technologies to enhance active, experiential learning as well as the risks of overload, distraction, and inequality that accompany their use.

Traditional education has been criticized for years for not embracing new disruptive technologies as part of their learning and teaching methods, despite the promising prospect of their reach and useful potential in this sphere (Scott, 2015). There has been a need for more research and theorization on this matter, which has provoked numerous studies on learning with the utilization of new VR\XR\AI instruments.

David Kolb, an American educational theorist, together with many others, made the case long before VR headsets were introduced to the general public as a common instrument for learning and teaching. One of the most widely cited frameworks is Kolb's Experiential Learning Theory (ELT). ELT sees learning as a cycle of doing, reflecting, conceptualizing, and experimenting. For instance, a nursing student can step into a virtual emergency ward, measure vitals, decide on treatment, and face the simulated consequences, all without putting a real living and breathing patient at risk. For another example, an architecture student can walk through a 3D model of the design they created before the first stone is laid, and funds and time spent. These examples seem assuring, however, there are rising questions and concerns. Some frameworks suggest that immersive environments really provide better learning and understanding results; others warn that these tools can overwhelm, distract, and even reinforce already existing inequalities.

A more targeted explanation comes from the Cognitive Affective Model of Immersive Learning (CAMIL), introduced by Makransky and Petersen (2021). CAMIL identifies six factors—situational interest, intrinsic motivation, self-efficacy, embodiment, cognitive load, and emotional regulation—that together shape the outcomes of immersive learning (Figure 1). This model helps researchers to understand how disruptive technologies, as well as psychological factors affect the efficiency of education.

Figure 1. Constructs that are included in CAMIL and the relationships between these constructs. Source: Makransky, Gram Møller, & Nordahl, 2020.



The model has intuitive appeal, but when applied in practice, empirical realities might contradict theory. As an instance, we can take situational interest: a VR reconstruction of the Roman Forum may instantly capture attention, yet whether that attention transforms into a sustained curiosity for archival sources or historical debates on the part of a participant remains questionable. Motivation may also be heightened by novelty, though once the initial sense of novelty diminishes, learners can lose patience and shift their attention if the assignment is perceived more like entertainment than a demanding, structured studying process.

Self-efficacy, described by Bandura (1993, 2006) as the belief in one's capacity to succeed, is another fragile element. Bandura (2006) argues that self-efficacy is a key determinant of human motivation and action, and that it should be measured with domain-specific instruments rather than generalized scales. He defines self-efficacy as individuals' beliefs in their capabilities to organize and execute the courses of action required to attain designated types of performances. Indeed, mastering a simulation can boost confidence, yet a poorly designed interface or a bout of motion sickness may just as easily convince a learner that they are "bad at technology," rather than "still learning while making mistakes and progress simultaneously."

Another important notion is embodiment. It is defined as integration of bodily action, cognition, and environment, where learning is grounded in sensorimotor processes. This term has roots in embodied cognition theory (Johnson-Glenberg et al, 2014; Thompson, Yarroch, & Rickard, 2018). Embodiment means that gestures, movement, and physical interaction are not just add-ons but central to how people think, understand, and learn within mixed reality and science education contexts. Moving an avatar may indeed strengthen the tie between learners' physical action and memory. Cognitive Load Theory (Sweller, 1988, 2011) further complicates the picture. The concerning aspect is that working memory is limited, and immersive environments can saturate it with excessive visual and auditory effects. Therefore, it becomes increasingly obvious that emotional regulation is as important as any other aspect of the educational process. Positive affect may sustain motivation (Mega et al., 2014), but, for instance, for a learner prone to anxiety, a high-pressure VR driving test could turn into an exercise in panic management rather than road safety.

Measurement raises yet another set of tricky and complicated questions. Traditional methods, such as exams, tests, and surveys, reveal some aspects of learning efficiency and learners' satisfaction, but not enough. To close the existing understanding gap, researchers have turned to psychophysiological measures: electrodermal activity to track arousal, heart-rate variability for stress, and eye-tracking for attention (Lohani et al., 2019; Rahal & Fiedler, 2019). These approaches may appear more objective, since they capture real-time responses, but their results can be ambiguous. Hence, such measures are useful as complements, but not as final verdicts.

Finally, the concept of "disruption" itself deserves a critical reflection as well. In the technology sector, disruption has recently become a badge of honour, that signals some major transformation or a breakthrough. In education, however, this concept is perceived as more double-edged. It is clear that immersive tools have the potential to redistribute authority and provide learners with more autonomy. They can also democratize access to experiences that in traditional educational models are limited to elite institutions. But disruption often mirrors and even reinforces existing divides, as wealthier educational institutions can afford costly infrastructure, while underfunded schools may struggle to maintain such basis necessary technologies as reliable Wi-Fi connection or access to digital educational platforms and libraries. Therefore, there is concern that the same set of tools that promises more affordable and easier access risk entrenching further inequality, disparities and even precarity.

To conclude, it is important to highlight that theoretical background, like Kolb's experiential model, CAMIL, Cognitive Load Theory, Bandura's self-efficacy, embodied cognition, and work on affect and motivation, does not produce a one-sided voice of approval for the new technologies in education. They highlight potential points of contention, challenges, and hidden hazards. The theoretical foundations, then, are not a manifesto for technology as such. They are a reminder that learning outcomes are shaped by how instruments, methods and approaches are used, by whom, and under what circumstances. Education has never been transformed by devices alone, and immersive technologies are unlikely to be the exception, and this is why it is crucial to reinforce their positive potential, conduct deep research into possible challenges and difficulties and provide clear recommendations for policymakers on the acceptable modes of integrating new technologies in key social spheres such as education with efficiency and positive outcomes. This is what e-DIPLOMA project is focusing on in the presented research.

Literature Review: Disruptive Technologies for E-Learning

Recent scholarship has put significant focus on the role of disruptive technologies in digital education. So-called immersive media such as VR, AR, MR, and XR, conversational AI and chatbots, as well as gamified environments, get particular attention after the COVID-19 global emergency. Virtual reality has been described as a technology that produces synthetic environments and creates an illusion of reality through manipulation of perceptual mechanisms (Slater, 2014), while augmented and mixed reality add digital layers to the physical world or combine real and virtual elements in real time, with extended reality serving as an umbrella concept. Research in social fields such as healthcare and teacher training has shown that immersive simulations can offer practice opportunities otherwise unavailable in traditional conventional education, as in VR training for infection prevention (Willis et al., 2022), chemotherapy safety (Chang & Hwang, 2021), classroom management (Chen, 2021; Delamarre et al., 2021), occupational safety (Ummihusna & Zairul, 2021), and tourism simulations (Chan et al., 2020).

Alongside immersive media, conversational AI has emerged as a promising but complex instrument, with chatbots designed on rule-based, retrieval-based or generative models (Cheddak et al., 2021) serving as tutors, peers, mediators, consultants, or motivational companions (Baylor, 2011; Pereira et al., 2023). Although valued for personalization and continuous support, their effectiveness strongly depends on the executed design, with some studies specifically drawing attention to the risks of distraction (Qin et al., 2020). Gamified virtual learning environments have also been widely applied international, introducing playful elements that allow learners to explore new experiences, interact in novel and creative ways, and simulate complex professional roles in the process of training (Castillo-Parra, 2022; Chan et al., 2020). Narratives and feedback loops within gamification have proven particularly influential in healthcare simulations (Buijs-Spanjers et al., 2020) and interdisciplinary contexts such as tourism education (Negruşa et al., 2015), although excessive competition and fatigue remain potential risks across difference educational fields.

These technologies are frequently embedded within established models of practice-based learning (Figure 2). Inquiry learning (Mayer, 2001; Lavoie, 1999; Thagard & Shelley, 2005; Hakkarainen, 2003), experiential learning (Kolb, 1984), action learning (Reynolds, 2011; Revans, 1998), simulations (Plass, Homer & Hayward, 2009; Rieber, 2005) and gamification (Khazaei et al., 2025) are often cited as theoretical frameworks. Yet the connection between specific pedagogical models and technological applications is not always made explicit. Research on interactivity shows that students engage with content at different levels: consumption, annotation, manipulation, submission, expansion, remixing and creation (Kurvits et al., 2015). Most e-learning practices with disruptive technologies remain at the lower levels, with learners acting primarily as consumers or simple manipulators, while only a few VR studies involve them as creators or c-creators of educational processes. This finding supports Mayer's (2021) critique that digital pedagogical designs often reproduce transmission-oriented models rather than genuinely learner-centred ones, thus, only reinforcing the existing imbalances in traditional education and conventional digital instruction.

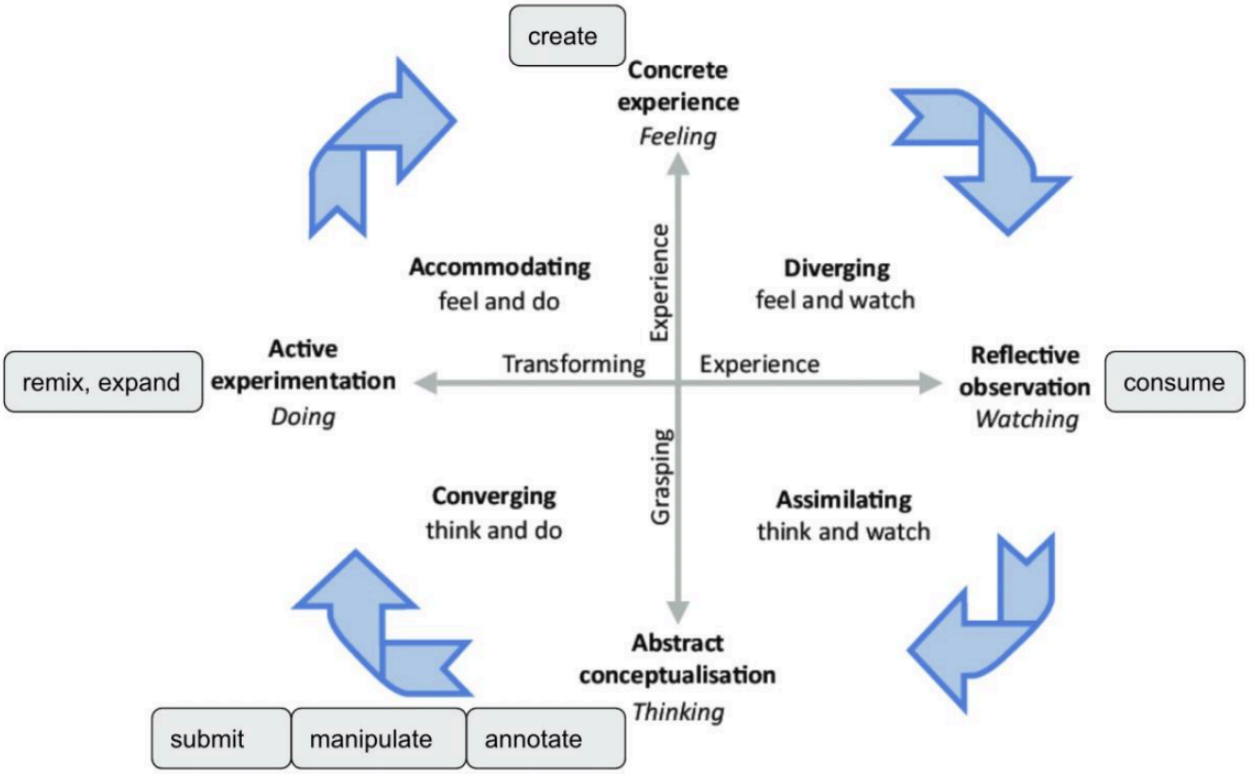


Figure 2. Experiential learning in relation to student interaction levels with the content and disruptive technologies.

Another important aspect that needs to be integrated in the analysis is scaffolding. The role of scaffolding (Figure 3) in educational environments is also extremely significant. It can be defined as "support provided by a teacher/parent, peer, or a computer- or a paper-based tool that allows students to meaningfully participate in and gain skill at a task that they would be unable to complete unaided" (Belland, 2014). Scaffolding as a form of support Following Vygotsky's (1978) concept of the zone of proximal development, researchers distinguish conceptual, metacognitive, procedural and strategic forms of support (Hannafin et al., 1999; Hill & Hannafin, 2001; Cagiltay, 2006), to which affective scaffolding has been added more recently (Steinert, Marin & Roeser, 2022; Sterelny, 2010; Candiotto & Dreon, 2021). In practice, conceptual scaffolding is often delivered through chatbots that adapt tasks and provide feedback (Kuhail et al., 2022), while VR environments can embed corrective or reinforcing feedback into narratives. Procedural scaffolding is particularly relevant in unfamiliar technological settings (Chen et al., 2021), and affective scaffolding, though less developed, has shown potential in immersive language learning that combines XR and AI to sustain motivation (Divekar et al., 2021).

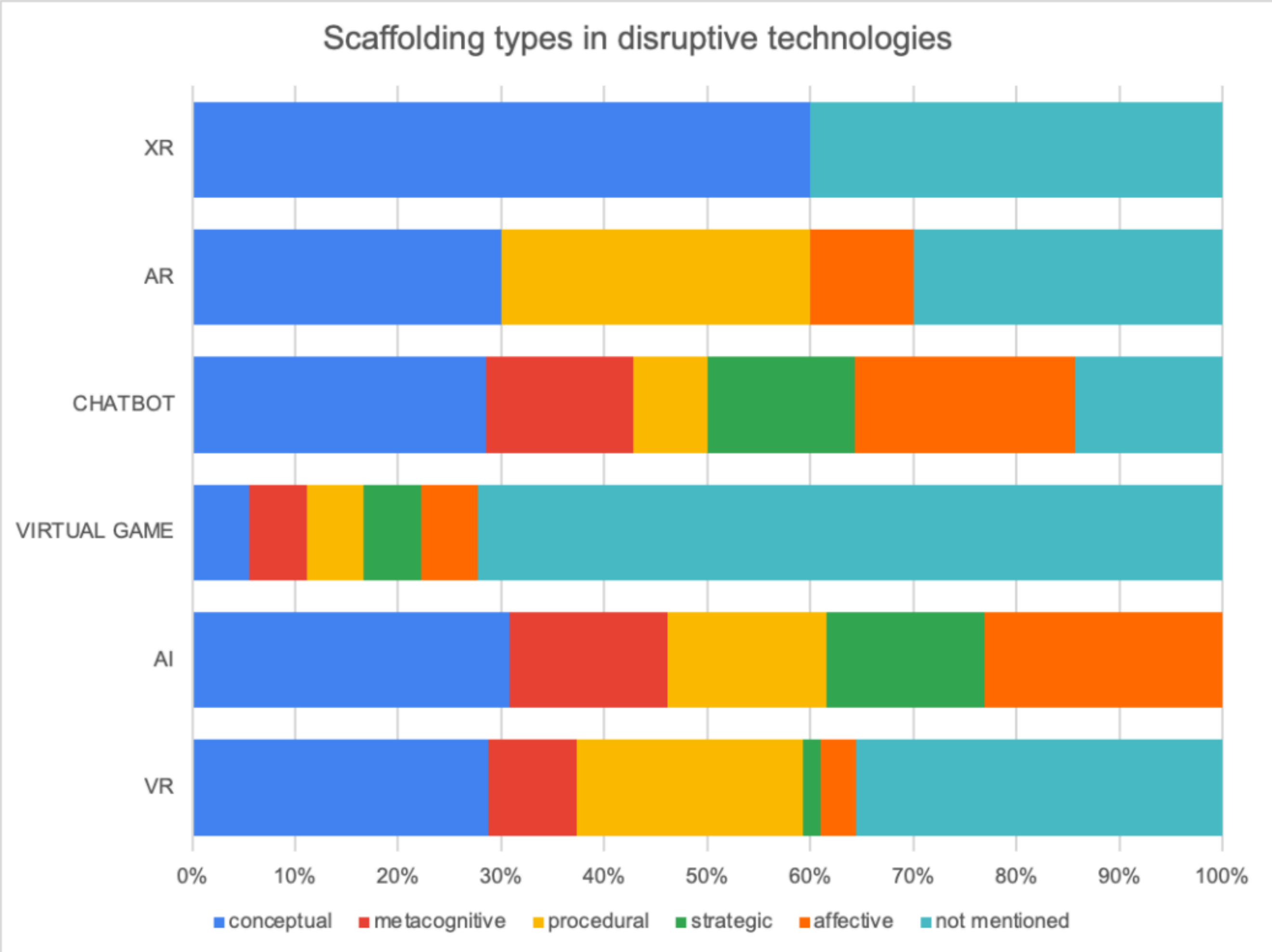


Figure 3. Scaffolding types in practice-based learning scenarios with disruptive technologies based on empirical literature review during the 1st step of the e-DIPLOMA project.

It should be noted that the social dimensions of learning with disruptive technologies remain relatively underexplored. Most studies still describe individual learning tasks in VR and AR environments (Ghosh, Rude-Parkins, & Kerrick, 2012; Johnston-Glenberg et al., 2021), while peer-to-peer or group-based approaches remain relatively rare and isolated. Existing examples include chatbots functioning as companions (Chen et al., 2022), AR-based collaborative activities (Alamäki et al., 2021) and AI-supported group discussions (Kuhail et al., 2022), but deeper concepts such as group dynamics, trust or polarisation, well established in social psychology (Sunstein, 1999; Myers & Lamm, 1975), are seldom addressed.

The documented learning outcomes of disruptive technologies can be categorized across four domains. In the cognitive domain, immersive and adaptive technologies have been linked to improved understanding and retention but at the same time to risks of distraction, increased fatigue and significant cognitive overload (Di Natale et al., 2020; Akgün, 2022; Ebadi & Ebadijalal, 2022). In the metacognitive domain, VR and gamification can support self-reflection and self-regulation through feedback and debriefing practices (Turner et al., 2003; Drigas et al., 2022), while immersion, social presence and gamified elements often enhance motivation and engagement of the affective domain (Asad et al., 2021; Cummings & Bailenson, 2016). At the same time, while immersive technologies hold considerable promise for enhancing engagement and learning, they also have the potential to elicit undesirable psychological states, including heightened levels of anxiety. (Kim, 2014; Wang et al., 2022).

To sum it up, according to the existing scholarship, disruptive technologies might offer significant potential for practice-based e-learning through simulations and gamified environments. Unfortunately, the research remains fragmented and needs further investigation. Among the most present problems are the fact that interactivity often stays at a superficial level, and scaffolding is inconsistently applied. Apart from that, social learning processes are underdeveloped, and empirical studies typically concentrate on narrow categories of outcomes without integrating cognitive and embodied effects.

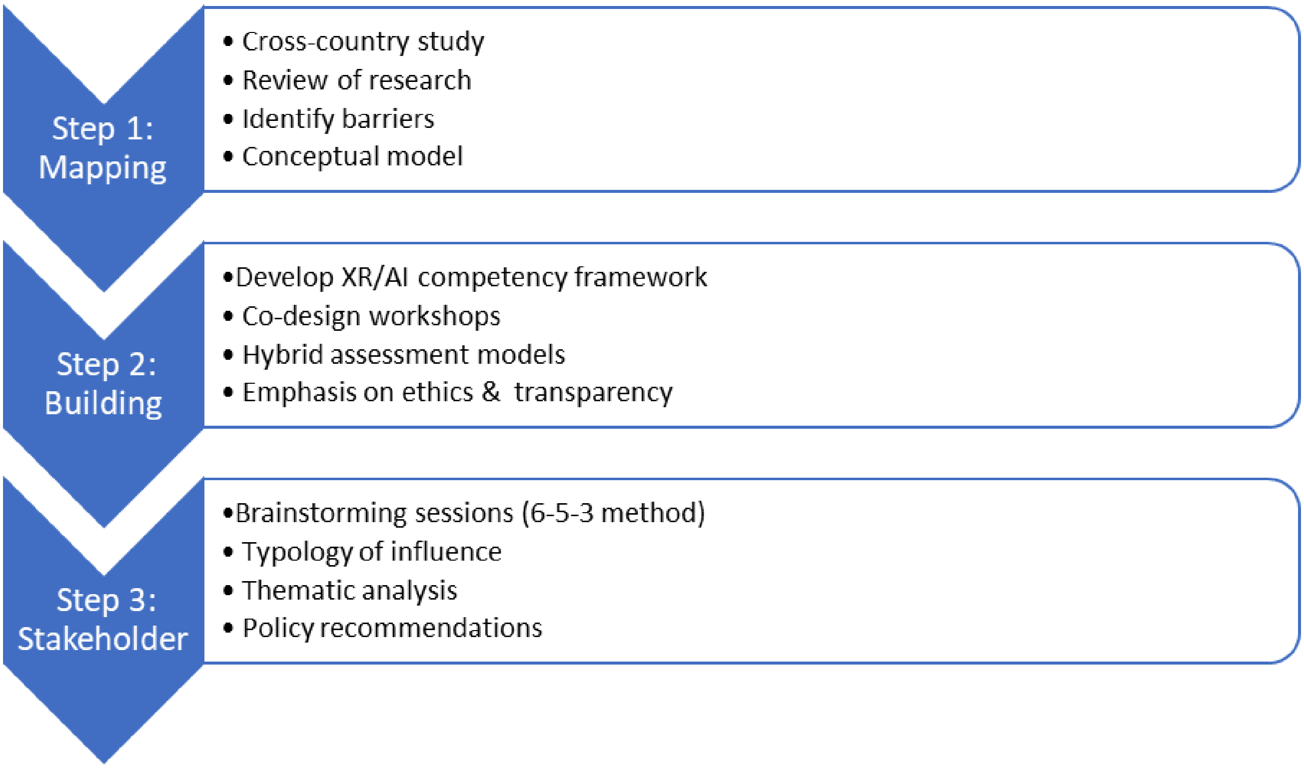
Methodological Framework of the e-DIPLOMA Project

The methodology of the e-DIPLOMA is built on the belief that introducing new technologies into the sphere of education and vocational training should not be a process purely in a top-down direction. It also should not be limited to a strictly technological routine. Instead, this project designed a participatory methodological framework that would allow for real interdisciplinary collaboration between all actors involved in the process of education, such as researchers, educators, families, policymakers, students, and developers. From the very beginning of this project, the aim was not simply to test a specific instrument, such as VR or AI, in the conditions of functioning classrooms, but to understand how they could be meaningfully and efficiently integrated into learning environments. Another important issue to resolve during this project was to understand how that integration could respond to the existing pedagogical needs and challenges at every level of the entire system in various national contexts of the European Union.

In order to meet these concerns, this project follows a methodological approach that includes three distinct phases (Figure 4). Each stage of the project is intertwined with the others. It is necessary to guarantee that practices and lessons learned at one step are actively embraces during the next. It unfolds over a long period of time and covers seven European countries, which have partnered for this project: Spain, Italy, the Netherlands, Estonia, Hungary, Cyprus and Bulgaria.

The e-DIPLOMA project operates within the broader framework of the European Union's strategic vision for 2024-2029, defined by the Commission's political guidelines and the ongoing Digital Education Action Plan (2021–2027). These initiatives place digital transition, inclusive growth, and human-centered technological innovation at the core of European policy. Within this framework, e-DIPLOMA responds directly to the EU's call to strengthen digital competences, promote equity in access to learning technologies, and ensure that artificial intelligence and immersive media are developed in line with European values of fairness, transparency, and inclusion. The e-DIPLOMA project was launched under the Horizon Europe call HORIZON-CL2-2021-TRANSFORMATIONS-01-05. This call invited innovative approaches to foster inclusiveness and resilience in education through advanced technologies such as AI, VR, XR, and robotics. e-DIPLOMA directly addresses these aims by exploring how disruptive technologies can enhance the development of twenty-first-century competences and by assessing their social and ethical implications across diverse European contexts.

Figure 4. Timeline of the e-DIPLOMA Methodological Framework



The first step is focusing on mapping the current state of the art in digital and immersive learning in seven European countries, that are involved in the project. The second phase of the project develops a competency framework and corresponding assessment metrics that are developed to fit the affordances and challenges of the disruptive technologies. During the third phase, the findings of the previous steps are transformed into concrete policy recommendations that rely on co-design methodologies, brainstorming techniques, and a participatory approach to policy drafting. With the three phases complete through an interactive and dynamic process, it ensures that the final recommendations are grounded in empirical evidence and the lived experience of diverse actors within different European educational ecosystems.

The final goal is to combine the construction of two extremely important dimensions, such as knowledge and trust, across a wide range of participants and institutions in a cross-national environment. And most importantly, it was to ensure that the final outcomes through policy recommendations are grounded in real-life experience, tested practices, and diverse gender-, age-, and abilities-informed perspectives.

Step 1. The Mapping of Ecosystems

The first step in the project was about answering a variety of critical questions that would allow us to employ the exploratory methodological approach. The questions to address are as follows:

- What types of digital learning environments already exist and have been tested in practice?
- What types of digital learning are efficient?

- What is the current situation at schools and universities in terms of the employment of disruptive technologies?
- What are the major problems, limitations, and challenges that educational institutions are facing as they proceed to integrate new technologies?
- What are the contextual variations between the six European countries in question?

In order to answer these questions, the partners within the project have carried out a detailed and thorough analysis of the current landscape of digital education. Throughout this process, they applied a specific focus on how learning takes place in online spaces and what vanishes in the process. Basing the work on previously published research, various EU papers and reports, as well as institutional strategies, this project explored one of the key problems arising from the current use of e-learning systems, which is too much focus on the content delivery and not enough on the interaction, embodiment, creativity, and student engagement. Many institutions had adopted digital platforms in response to the COVID-19 crisis in a stressful and urgent environment, which led to the fact that the new toolkit was often ill-suited to sustain learners' engagement and enable hands-on practices. This leads to such negative consequences as the lack of the necessary depth and human nature of the education, networking and interaction, without which much of the learning process becomes meaningless and even distressful.

The first step also includes cross-national comparative research, which allows us to understand the similarities and the differences across various European educational systems. A span of critical barriers and educational gaps was defined as a result of the cross-country analysis. First, educators very often struggled to adapt existing pedagogical programs and strategies to digital formats. Secondly, there is an alarmingly widespread lack of training and institutional capacities. The project also identified major disparities in infrastructure and devices, as well as inequality in accessibility to digital skills, which appear to promote further imbalance among disadvantaged learners and under-resourced schools. This report will proceed with a more detailed explanation and analysis of the results of the first step.

On the basis of this diagnostic work, the project built a conceptual model of the e-learning ecosystem. The ecosystem here is defined as a complex multilevel structure, influenced by a variety of technological, institutional, and cultural factors. And that is why this model was constructed as a flexible analytical tool, rather than a static description of reality, that exists only in a fixed moment of time. It is seeking to provide a framework for situating digital tools within broader educational processes and identifying what appears to be key entry points for innovation. In addition, a set of guiding values and principles was articulated during the mapping to inform design criteria for further recommendations within broader educational and societal contexts. This set will also be discussed in the following chapters.

It is important to note, that mapping of the e-learning ecosystems in seven participating European countries was critically important for the assessment of the current state of the art in the educational sphere and for the preparation for the second phase.

Step 2. Building Up Competency and Assessment Frameworks

The second phase of the e-DIPLOMA project set out to build a pedagogical foundation for bringing XR, VR, and AI into formal education on different levels and in diverse national contexts. The idea was not simply to introduce new tools, but to ask what kinds of learning they might realistically support and how such learning should be assessed. Immersive and intelligent technologies appear to demand different forms of engagement than conventional digital education, and this phase of the project tried to pin down which competencies matter most in such environments. It also sought to design ways of measuring them that would be meaningful, ethical, and sensitive to the contexts in which learners actually study.

This work began with the development of a competency framework designed specifically for immersive learning. The team drew on existing European reference points, such as the Key Competences for Lifelong Learning and DigComp (2018). According to the Council recommendations, Key competences include knowledge, skills, and attitudes needed by all for personal fulfilment and development, employability, social inclusion, and active citizenship. The e-DIPLOMA project adapted them with the particular challenges of VR, XR and AI in mind. The framework was not limited to technical skills. Social-emotional and cognitive dimensions were also included, although surprisingly often they get overlooked. Examples of the employed approach in real life can be as follows: the ability to interpret visual and spatial data, or the capacity of a citizen to reflect critically on the feedback provided by AI systems. Although from the first glance such abilities can seem obvious and straightforward, in practice they raise difficult questions about learners' engagement with technology and with each other.

To avoid building an abstract model disconnected from reality, the project team worked closely with educators, students, their families, and developers. Co-design workshops and iterative feedback sessions shaped the framework so that it responded to classroom needs rather than just research ambitions. Competencies were grouped into three domains—cognitive, affective, and embodied—an acknowledgement that learning in VR,XR/AI settings involves more than the acquisition of abstract knowledge, but rather engages affective and experiential dimensions of the educational process. Attention was also paid to educational institutions, responding to one of the most pressing questions: could immersive tools be used to support learners from different backgrounds? The answer seems to be yes in some cases, but only if careful thought is given to accessibility and pedagogy aspects.

Assessment proved an even greater challenge. Standard evaluation tools looked ill-suited to experiences that are fluid, participatory, and highly contextual. To address this, e-DIPLOMA put forward a hybrid model that combined traditional methods—observation grids, self-assessment rubrics, teacher commentary—with new approaches made possible by AI and sensor data. For instance, an immersive simulation might record patterns of collaboration or adaptability, while algorithms could generate tailored feedback in real time. Such possibilities are attractive, yet they also raise concerns: How reliable are these data traces? Can they be interpreted without oversimplifying complex learning behaviours?

The project voiced caution about relying too heavily on AI in assessment, particularly when algorithms generate scores without making their logic visible. Hidden processes of this kind, it suggested, risk eroding both fairness and trust. To counter this, the authors argued for data policies that spell out more clearly how information is collected and applied, so that learners and educators can see what lies behind the results. They also pointed out that machines should not be left to stand in for teachers. Human interpretation remains essential, since professional judgment can catch nuances that automated feedback will inevitably miss. A further thread running through the discussion was the concern for learner agency. Learner agency, in particular, was seen as something that must not be lost in the excitement about AI-driven evaluation.

In the end, the competency and assessment frameworks developed in this phase provided the scaffolding for later design and testing of immersive learning prototypes. In the e-DIPLOMA project, three prototypes were developed to explore different ways VR, XR and AI might be brought into teaching and learning. One of them experiments with block-based programming linked to sensor interactions in extended reality. Instead of working only on a screen, students can try out code through embodied tasks, which makes abstract logic more tangible and supports the early stages of computational thinking. Another prototype turns to questions of social entrepreneurship. Students enter XR scenarios that place them in the middle of community problems—designing, for example, a response to local waste management or thinking through how to support a neighborhood initiative. The point here is less about mastering technical features and more about giving learners room to exercise agency, test ideas together, and confront the ethical trade-offs that inevitably arise. The third prototype uses virtual reality to add something extra to ordinary lessons, particularly in science and history. This prototype intends to teach, survey, and inspire the use of VR solutions in education. All these instruments also served as a link between research and policy, suggesting not only what learners might be expected to achieve but also how education systems could fairly support and evaluate them. Step 2, in that sense, did not treat technology as an end in itself. It rather positioned XR, VR, and AI within a broader pedagogical vision that acknowledges both their potential and their limits.

Step 3. Stakeholder Engagement and Policy Co-Creation

The third phase of the e-DIPLOMA project marked a move away from diagnostic and design work toward something more political: participatory policy-making. The principle at its core was that individuals most affected by educational technologies should be part of the conversations that shape them. Ensuring that teachers, learners, and their family members, policymakers, and developers were seen as active contributors and not as passive recipients of policy was essential. This was organized with the help of consultation, co-creation, and structured participatory methods. As a result, this eventually produced a set of policy recommendations grounded in everyday realities and lived experiences rather than mere theory.

This participatory shift was supported by co-design methodologies developed and tested earlier in the project. Drawing on experiences from learning module design, the team adapted co-design tools. Cognitive walkthroughs, persona-based user scenarios, activity mapping, and value elicitation, in the policy context, were among those tools. They were used to frame discussions and encourage inclusive engagement during workshops. Hackathons, which were conducted in the project's earlier phases, also played a huge role. A hackathon is an event that brings together experts and creates a collaborative environment for solving a certain problem. Sometimes hackathons could have competitive elements to motivate participants. They were open to a wider public who have experience with e-learning (in higher educational, vocational educational, and EdTech training companies' context). Input from hackathons was used to improve the e-DIPLOMA platform's early prototypes. These tools provided firsthand insight into how users interact with emerging systems and highlighted practical experiences that were later used for policy discussion. The results of these co-design activities (feedback and recommendations from students, educators, and developers) served as a valuable foundation for Step 3, as they allowed policy-making to build directly on the outcomes of experimentation and collaborative prototyping.

To gather perspectives systematically, the project used a three-tier typology of influence. At the “low-influence” end were students and families, which are people whose daily experience of technology is direct but whose formal power might be limited. In the middle were teachers, school staff, and developers, who sit closer to the practical levers of implementation. At the “high-influence” level were school leaders, policymakers, and experts, whose decisions carry real weight. This structure was useful in making sure different voices were heard, though one could argue that it risked oversimplifying the messy overlaps between categories. Some teachers wield far more influence than others, and not all policymakers are equally powerful.

The main activity of this phase was a series of brainstorming sessions held in each of the seven partner countries. Organizers drew on the 6-5-3 method, where six participants produce and reflect on five ideas over three rounds. Adapted to policy-making, the method was supported by guides, templates, and a defined workflow. All brainstorming sessions and participatory activities were conducted in accordance with ethical research standards. Every participant signed an informed consent form prior to taking part, ensuring voluntary participation and transparent use of collected inputs for analytical and policy-development purposes. Trained moderators kept things moving, while standardized documentation helped make the sessions comparable. In reality, though, group dynamics varied significantly. Some sessions produced bold systemic ideas, such as, integrating XR labs into national curricula, while others stayed closer to practical fixes, like providing training modules for teachers who had never used a headset before.

The process itself followed a structured progression. First, participants identified a specific challenge in using VR,XR or AI in education. Next, they proposed possible policy responses, and finally, they refined these responses collectively. Discussions were often sparked by real case studies or design prototypes developed in previous project phases, including those tested during hackathons and co-design workshops. These served as touchpoints that grounded policy conversations in concrete examples. Thematic prompts—such as equity, teacher training, or infrastructure—also helped shape the dialogue. Recognising that not everyone would be comfortable with policy jargon, the team developed a simplified input template for students and families. That adjustment may seem minor; however, it mattered. The process became less intimidating and gave space to voices that might otherwise have stayed quiet.

The template did not include a sophisticated element. Participants listed a title, described the problem, suggested possible actions, and closed with a justification of the idea’s value. Alongside generating proposals, participants were asked to assess their potential consequences and ethical dimensions. They reviewed each other’s contributions, while facilitators stepped in when needed to keep the tone constructive. This structure opened up different layers of conversation. Sometimes it encouraged horizontal dialogue, as when students challenged teacher assumptions, and sometimes vertical comparisons, when perspectives from families, practitioners, and policymakers were connected.

After the sessions, the team carried out thematic analysis of the ideas. Proposals were grouped under headings such as digital pedagogy, teacher capacity, data privacy, or accessibility. Cross-country patterns were identified, and contributions were checked against the values established in Step 1 (inclusion, trust, autonomy, sustainability, adaptability) and the competency framework developed in Step 2. Selected proposals were discussed further during synthesis workshops. In the end, the recommendations showed convergence in some areas and divergence in others. That mix illustrates an important point: participatory policy-making is seldom tidy and tends to focus more on navigating tensions than on forcing full consensus.

The final output of this phase was a policy report that functions as a strategic document built on collective intelligence. It balances bottom-up creativity with system-level needs and attempts to bridge the distance between classroom experimentation and institutional change. In that sense, Step 3 did not simply produce “recommendations” but tested a method: a way of doing educational policy that is inclusive, transparent, and open to critique. Whether such a model will extend beyond the project remains to be seen, but it offers a direction for making digital education policy less technocratic and more democratic.

Phase	Focus & Objectives	Key Activities	Outputs & Contributions
Step 1: Mapping of Ecosystems	Diagnose current state of digital and immersive learning across six European countries; identify barriers, gaps, and variations.	- Comparative research (Italy, Spain, Netherlands, Estonia, Hungary, Cyprus, Bulgaria). - Review of EU papers, institutional strategies, existing platforms. - Analysis of pedagogical and infrastructural challenges. - Cross-national comparison of ecosystems.	- Conceptual model of e-learning ecosystems. - Identification of critical barriers: lack of training, inadequate infrastructure, pedagogical adaptation difficulties, inequality in access. - Guiding values and principles for design (inclusion, interaction, engagement).
Step 2: Building Competency & Assessment Frameworks	Define what kinds of learning XR/VR/AI can realistically support; design meaningful, ethical, and context-sensitive assessment tools.	- Development of competency framework (cognitive, affective, embodied domains). - Co-design workshops with educators, students, developers. - Iterative feedback loops.	- Adapted framework aligned with DigComp & Key Competences for Lifelong Learning. - Inclusion of social-emotional and cognitive dimensions. - Hybrid model for assessment (traditional + AI-driven). - Emphasis on transparency, learner agency, and ethical oversight.

		- Exploration of hybrid assessment combining traditional tools with AI/sensor data.	
Step 3: Stakeholder Engagement & Policy Co-Creation	Translate findings into participatory policy recommendations; ensure inclusive involvement of actors across influence levels.	- Brainstorming sessions in partner countries (6-5-3 method). - Use of co-design tools (personas, activity mapping, value elicitation). - Typology of influence (low, moderate, high). - Synthesis workshops and thematic analysis of proposals.	- Policy recommendations grounded in empirical evidence and lived experience. - Strategic report reflecting collective intelligence. - Inclusive, transparent policy-making method tested. - Balance between bottom-up creativity and system-level needs.

Foundational Principles

The policy recommendations in this report are built on a set of guiding principles (Table 2) that informed every stage of the e-DIPLOMA project. They ran like a thread from the first mapping of the digital learning ecosystem, through the design of the competency framework, to the co-creation of ideas with stakeholders and the final drafting of policies. These principles are not window dressing. They emerged in response to weaknesses in post-COVID-19 e-learning. These principles were then tested and refined through dialogue with participants in seven European countries. Their purpose is twofold. First, to suggest what digital education should strive toward, and second, to offer tangible criteria for assessing whether immersive environments are inclusive, sustainable, and likely to be genuinely valuable.

The origins of these principles lie in dialogue across sectors and in comparative research. Early on, partners asked what was missing from existing virtual education. The answers, while not surprising, were telling: authentic interaction, real learner agency, pedagogy that could adapt rather than bend to the tool, emotional engagement, and stronger links to institutional practice. The absence of these features became painfully clear in disadvantaged conditions. For many vulnerable learners, the shift to "emergency" online teaching made things worse; it increased their sense of isolation and sharpened the feeling of being left behind. Stories like these show that the failures were symptoms of deeper structural flaws in digital education. In response, the project tried to build a set of principles meant to reformulate how future systems are built and judged.

<u>Inclusion and Equity</u>

Inclusion and equity guide the e-DIPLOMA project's vision for digital education. Their relevance became stark during the COVID-19 crisis. As classes moved online, the shift revealed cracks that had long been there. In rural regions, connections frequently failed. The problem was also clear in urban centers: families with more than one child often had just a single laptop to share.

In this context, the project began from the supposition that technologies like VR, XR, and AI are not neutral. While they can expand opportunities, they can also reinforce inequality. This recognition shaped the work throughout. Inclusion was not defined narrowly as access to devices or broadband. Instead, it was understood as the ability to participate meaningfully, to have individual needs taken seriously, and to see lived experiences reflected in the design of digital environments.

The co-creation process gave this commitment practical form. Rather than limiting consultation to established voices, the project made a point of engaging learners and educators from disadvantaged contexts. By simplifying the templates into plain language, the project lowered barriers to participation and removed the need for technical policy expertise. Facilitators were also trained to welcome different forms of input. The proposals that emerged carried the marks of everyday experience, such as struggling with weak connections in rural schools, balancing home responsibilities with study, or trying to use platforms that were not accessible, rather than abstract formulations detached from reality. Immersive tools themselves show promise for inclusion, but only under certain conditions. A virtual science lab, for instance, can give access to experiments that would otherwise be blocked by cost or on other considerations. Simulated environments can be adapted for learners with disabilities. AI feedback systems can, in principle, support students to progress at their own pace. But none of this is guaranteed. Without inclusive design practices and institutions willing to commit resources, the same tools risk reinforcing old hierarchies under a new digital skin.

Nevertheless, the real-world implementation of co-creation is often far more complex. That said, the project's experimentation with participatory design also revealed just how embedded resistance to co-creation practices can be. Institutional cultures tend to reward efficiency and hierarchy, not mutual vulnerability or shared authorship. Co-creation, as many educators noted during brainstorming sessions, demands time, trust, and a willingness to loosen one's grip on control. These qualities can feel at odds with the pace of digital transformation or the demands of curriculum targets. It is confirmed by the extensive research in the field (Bovill et al., 2016). In more than one case, teachers admitted to feeling caught between wanting to include students and fearing the loss of structure or authority. However, this friction is not necessarily a sign of failure. As Cook-Sather, Bovill, and Felten (2014) suggest, productive co-creation involves not just agreement, but also disagreement, negotiation, and discomfort. The very act of working through conflicting assumptions, for instance, about what counts as knowledge, who has the right to shape learning environments, and how much power is genuinely shareable, can serve as a form of pedagogical learning in itself. Still, this assumes that all actors are entering the conversation from more or less stable positions, which is rarely the case.

Inclusion was also treated as systemic, extending well beyond classrooms or platforms. National policy priorities and funding streams all shaped what was possible. Since the project involved seven countries, it could identify both broad patterns and local details. Regional gaps in digital infrastructure were evident, while in some contexts the more urgent problem was a shortage of teacher training. These were reflected in the final recommendations, which were tested not only against educational ideals but also against administrative feasibility.

Finally, inclusion was not treated as a fixed box to tick but as a moving target. It required adjustment, reflection, and constant negotiation. Tools were revised, workshops were adapted, and feedback was folded back in. Equity, in this view, was not a brake on innovation but its precondition. Without it, immersive and intelligent technologies are likely to reproduce the very exclusions they claim to solve. With it, they may create opportunities for learners who have historically been excluded to participate and thrive.

Autonomy and Learner Agency

The e-DIPLOMA project treats learner autonomy and agency as central to meaningful digital education, especially in immersive environments shaped by VR,XR and AI. Autonomy in this context is an ongoing process in which learners make decisions and reflect on the course of their own education. From the beginning, the project worked to put these ideas into practice by encouraging learners to move from passive roles to active roles as co-creators of their learning.

This orientation was translated into the competency framework. Alongside technical and subject-based knowledge, it highlighted skills tied to self-regulation and reflection. In practice, this meant designing environments where feedback was immediate, and learners had space to reorient themselves when their first approach did not work. Assessment design was not limited to conventional tests. It drew on real-time feedback and interactive support built directly into XR environments. These tools went beyond simply recording outcomes. They opened space for learners to stop, consider their choices, and adjust their approach. In practice, this sometimes meant receiving prompts to rethink a decision mid-task or being given immediate insight into how a different strategy might change the result. Rather than treating assessment as an endpoint, the project treated it as part of the learning process itself.

Immersive environments provide affordances for autonomy that are harder to achieve in more conventional digital platforms. XR simulations can place learners in complex situations that call for judgment. Virtual labs, for instance, allow experimentation in safe but realistic settings, where actions have visible consequences. Recent research suggests that one of VR's distinctive contributions to education lies in how it establishes a sense of agency, giving learners a chance to participate in tasks and contexts they would otherwise never experience in a classroom. It is stressed that learners should be offered meaningful choices in how they interact with immersive environments. These choices sit alongside concerns with accessibility, opportunities for social engagement, and assessment design.

Drawing on these insights, the e-DIPLOMA project has attempted to create immersive scenarios that enable exploration and experimentation. Learners were encouraged to try, to adapt, and sometimes to fail constructively in settings ranging from professional simulations to collaborative spaces. Here, education is framed not as something delivered, but as a process shaped actively by learners, with guidance and context provided through both immersive technology and human facilitation.

Autonomy and agency in e-DIPLOMA are not treated as abstract ideals. They shape real decisions about the design of learning experiences and about how those experiences are assessed. The project's position appears clear: educational technologies should not only deliver knowledge, they should help learners develop the capacity to steer their own paths and, in doing so, to alter both themselves and the environments in which they act.

Trust and Transparency

Trust and transparency are treated in the e-DIPLOMA project not as slogans but as conditions for making immersive technologies work responsibly in education. Their relevance becomes most visible when systems rely on artificial intelligence or learning data that, whether intended or not, can influence how people learn. The project's stance is straightforward but not trivial: without trust, even well-designed interventions are likely to falter.

Transparency begins with clarity about what tools are doing in practice. Immersive systems often track interactions and measure levels of engagement in real time. If learners and educators are not told what is being observed and how the data is processed, trust quickly erodes. It has to be earned through repeated, open communication and through governance that shows its work. Institutions that explain why data is collected and create mechanisms for independent review are more likely to foster engagement. Without such measures, scepticism or disengagement is almost inevitable. For this reason, e-DIPLOMA's evaluation strategy required AI-based assessment tools to be explainable, offering users some insight into how they operated rather than hiding their processes in a sealed box.

Trust also depends on human oversight and ethical boundaries. AI and XR tools should support decision-making, not replace it. Within e-DIPLOMA, analytics and feedback systems were always designed to complement the role of educators. Teachers remained the ones who interpreted the data, framed feedback, and decided how best to act on it. This balance appears to be essential if technology is to strengthen rather than weaken human agency.

Institutional commitment played its part as well. Trust is not sustained by tools alone but by the culture in which they are introduced. A digital transformation grounded in value-driven design, shared scrutiny, and accountable governance is more likely to take root. The project tried to apply this approach into its co-creation and policy development processes. According to both European Union and the OECD standards protecting data privacy and maintaining transparency in the use of educational technologies are essential which resonates with the e-DIPLOMA principles. The reciprocal relationship shaped both the design choices and the policy logic of e-DIPLOMA. The project may suggest that when educational technologies are built to be accountable, clear, and human-centered, they are less likely to be seen as a risk and more likely to act as a catalyst for meaningful educational change.

Adaptability and Context-Sensitivity

It is widely understood that education in the digital age has to stay open, responsive, accessible, and willing to adapt to the shifting realities of learners and institutions. The e-DIPLOMA project treated adaptability and sensitivity to context not as optional ideals but as working principles for making immersive technologies such as XR and AI meaningful in practice.

Adaptability in this sense does not imply a universal recipe. It seems instead to call for systems that bend toward local conditions, responding to what schools and teachers actually face. Comparative work across six European countries revealed striking differences: some classrooms operated with strong broadband and administrative support, while others coped with unstable connections, few trained staff, or bureaucratic routines that left little room for experimentation. These contrasts suggest that technology strategies cannot be handed down in rigid form. They need to give educators space to adjust content, pacing, and support to the realities they know best.

When prototypes were designed, flexibility remained central. Activities were built so they could scale up in high-tech labs or be pared down in schools with limited devices. Teachers could shift competencies, rewrite assessment tasks, or reshape scenarios according to what their learners could handle. This design approach may look modest, but it resisted the common temptation to assume every institution can or should work the same way.

The same principle guided co-creation sessions. Workshops were scheduled with national calendars in mind and adjusted to different policy environments. Some were framed around centralized systems, others leaned on local, community-based structures. Language barriers were addressed directly, with materials tailored so participants could express their ideas without being forced into unfamiliar jargon. These adjustments encouraged stronger participation, but they also meant that the resulting policy ideas were tied to lived realities rather than abstract templates.

<u>Sustainability and Long-Term Impact</u>

Educational projects often fade once their pilot phases end. e-DIPLOMA was conceived with that risk in mind, aiming not just to test new tools but to build conditions for their survival and growth. Sustainability here does not only refer to budgets or environmental responsibility. It also points to whether immersive technologies such as XR and AI will carry educational, institutional, and pedagogical value that lasts. From the outset, the project tried to orient its work toward long-term benefits: tools that could be scaled, models that could shift with context, and a policy environment likely to support change over time.

Prototype design reflected this ambition. Components—simulations, feedback systems, evaluation tools—were deliberately built to be modular and transferable. They were not tied to a single curriculum or locked into a specific device. Instead, they rested on principles that educators could adapt to local conditions. A well-resourced school might deploy them in a digital lab, while another with fewer resources could still reshape them to fit its classrooms. This adaptability may suggest why schools are more likely to integrate immersive tools gradually and keep them in use, rather than treat them as passing experiments.

Another focus was ensuring that responsibility for adoption did not rest with a few enthusiastic teachers. Many educational innovations falter because once those individuals leave, the practice vanishes with them. To avoid this, e-DIPLOMA deliberately involved policymakers, administrators, and teacher trainers in co-design. Their participation helped shift immersive tools from the margins of experimentation toward the mainstream of institutional practice. Whether this will endure remains uncertain, but the effort created pathways for sustained budgeting, curriculum alignment, and long-term endorsement.

Competency frameworks and assessment design were woven into this logic of sustainability. By embedding VR,XR and AI within competence models already recognized in Europe, the project aimed to normalize their use. Once a tool becomes part of official standards, it is harder to dismiss as a novelty. Teacher education, professional development, and curriculum planning begin to treat it as part of ordinary expectations.

Still, sustainability cannot be reduced to frameworks and structures. Education is constantly unsettled by shifting policy priorities, technological change, and social demands. Any tool that lasts must evolve. e-DIPLOMA addressed this uncertainty by building feedback loops into its design process. Stakeholder reflection and iterative development allowed prototypes, frameworks, and policies to adapt over time. This flexibility appears crucial to keeping immersive tools relevant as needs change.

Operationalizing Values into Practice

Turning values into practice requires design choices that make those values tangible, evaluation processes that question their effectiveness, and institutional support that keeps them alive over time. In the e-DIPLOMA project, values such as inclusion, autonomy, trust, adaptability, and sustainability were worked into the details of design, co-creation, assessment, and policy development.

Governance design also mattered. A multi-phase methodology created feedback loops, where stakeholder reflection directly affected prototypes and policy scenarios. This iterative structure meant that values were not frozen at the outset. They were revisited, adjusted, and sometimes challenged, which helped maintain both trust and adaptability.

When it came to policy recommendations, values were again made operational. Proposals for immersive learning ecosystems did not stop at technical guidelines. They extended to institutional strategies: professional learning initiatives, transparent procurement practices, and support mechanisms that could adjust to different contexts. These proposals showed how values could migrate from aspiration into concrete policy language.

What emerges from this work is a reminder that values are only meaningful when carried through into practice. Evidence from design research and policy studies suggests that alignment between mission and action is rarely automatic. It requires strategies that may look procedural, such as co-creation with diverse groups, explainable assessment, or embedding new practices into institutions, but are, in fact, where values live or die. By making these strategies part of every phase, e-DIPLOMA shifted values from guiding metaphors into working instruments capable of shaping sustainable, inclusive educational change.

Table 2. Foundational Principles Summary

Foundational Principle	Core Meaning	Application in e-DIPLOMA Project
Inclusion and Equity	Ensuring all learners can participate meaningfully, especially those in disadvantaged contexts	Recognized technology as non-neutral; addressed infrastructural gaps and social inequalities; co-created with marginalized learners and educators; simplified

		language in templates; trained facilitators; promoted systemic inclusion in policy, design, and access. Focused on adaptability to real-life contexts, not just device access.
Autonomy and Learner Agency	Enabling learners to take ownership of their learning process	Integrated into the competency framework and XR assessment design; created environments allowing experimentation, reflection, and real-time feedback; emphasized co-creation with learners; used simulations to develop decision-making and metacognitive skills; promoted active over passive learning experiences.
Trust and Transparency	Building confidence in technology use by being open about its mechanisms and limitations	Required explainable AI tools; involved educators in feedback interpretation; stressed human oversight; emphasized value-driven institutional culture; encouraged governance that included open communication, ethical data use, and alignment with EU/OECD standards for educational technologies.
Adaptability and Context-Sensitivity	Designing tools and policies that adjust to local needs and realities	Resisted one-size-fits-all models; designed flexible prototypes; considered national calendars and educational structures; adjusted workshops and materials for cultural and linguistic contexts; respected regional infrastructure variations; framed adaptability as a condition for success, not an exception.
Sustainability and Long-Term Impact	Embedding immersive tech in lasting institutional frameworks and making adoption scalable and transferable	Built modular, curriculum-independent prototypes; involved teacher trainers, policymakers, and administrators to avoid isolated innovation; aligned tools with EU competence frameworks; supported iterative development and stakeholder feedback; emphasized durability of practices beyond project lifespan.
Operationalizing Values into Practice	Translating principles into real design choices, evaluation methods, and policy actions	Ensured values were embedded in every phase—design, assessment, stakeholder engagement, and governance; used iterative methodology to revisit and refine values; linked values to concrete outputs like procurement strategies, professional learning plans, and institutional support structures.

Pedagogical and Systemic Context. Challenges and Barriers.

Understanding the difference between e-learning and traditional instruction is essential for identifying best practices in the integration of VR, XR/AI in education. Traditional instruction depends on the physical classroom — people in the same space, routines that become second nature, the small cues that guide attention and feedback. Online learning unsettles much of that. It changes who initiates interaction, how quickly responses come, and how much responsibility shifts toward the learner. These differences matter because immersive tools build on exactly those dynamics. They can expand engagement, but only if institutions rethink the assumptions that still shape their teaching methods. Otherwise, VR, XR and AI risk reproducing the same limitations they promise to overcome.

In many regions globally, graduates and teachers believe that conventional personalized and direct learning techniques help enhance writing abilities and personal identity. Undergraduate students and experts are driven by interpersonal abilities since they desire to understand the optimal method to handle specific situations. Conventional schooling can offer dialogue, encouragement, cost-effectiveness, coordination, and additional advantages for students in post-secondary education and others.

While traditional education provides interpersonal support and clear and predictable structure, and digital education offers flexibility, disruptive instruction aspires to combine both, addressing their limitations at the same time. Hence, there are differences not only between traditional learning and digital learning, but there are also particularities that are inherent to disruptive technologies in education, that separate them from the conventional digital learning (Table 1).

Table 1. Difference between traditional learning, conventional digital learning, and disruptive learning

Dimension	**Traditional Learning**	**Conventional Digital Learning**	**Disruptive Learning**
Modality	Offline	Online platforms	Immersive hybrid environments
Time and Location	Fixed schedule and place	Flexible location and timeschedule	Context-aware, possible to embed in real-world environments
Learning Pace	Instructor-based	Adaptable	Based on real-time learner performance
Cooperation	Encouraged coordination with peers and instructors	Often isolated	Encouraged real-time collaboration through avatars, shared tasks, and simulations
Instructor Role	Knowledge transmitter	Technical support, content curator	Mentor, facilitator, learning experience designer
Motivation and	External motivation	Varies widely, heavily	Emotionally engaging

Engagement	through grades and summative assessment	dependent on social, economic conditions	through high learner presence and immersive technologies
Source of Knowledge	Instructor-centered	Digital content-based	Dynamic interaction with tutors and peers
Communication	High value of verbal and non-verbal interpersonal interactions	Limited or asynchronous communication	Real-time immersive environments, social presence instruments in XR spaces
Pedagogical Focus	Focus on cognitive development and content acquisition	Focus on content delivery	Focus on cognitive, embodied learning integrated
Curriculum Structure	Fixed subjects and timetables	Possible modularity and flexible structure of the curriculum	Interdisciplinary, modular curriculum
Assessment	Primarily summative	Mostly quizzes and tests, limited feedback	Continuous, formative, personalized with real-time feedback
Scalability	Dependent on physical capacities	Scalable, but constrained by the modality	Highly scalable, pedagogically flexible
Data and Feedback	Miniman data use, mostly frades-oriented feedback	Limited personalization and performance tracking	Real-time analytics and adaptations with privacy safeguards
Equity Considerations	Very dependent on local resources and social and economic environments	Varies drastically across regions	Requires targeted political focus on equal technological provision, holds potential for reducing inequalities if designed accordingly
Security and Privacy	Low concerns due to the physical environment	Growing concerns about surveillance and data privacy	High concern, as clear regulations are needed, especially for minors
Wellbeing Support	Possibility for instructors to monitor and support student well-being in real time	Very difficult to track student well-being	Potential to integrate mental health checks, personalized support

Real-Worl Application	Limited to field trips or labs	Often theoretical, screen-based	Authentic, simulated environments for practice-based learning

The pandemic didn't just push schools and universities online—it revealed, sometimes painfully, just how unstable our digital pedagogy and governance frameworks really are. Reviews of the last decade suggest that while platforms and digital content have become more sophisticated, the systems meant to deliver fair and meaningful learning have lagged behind. It is possible to see it in the gaps: when connections were weak or devices were unavailable, students disappeared from classrooms. When digital skills were uneven, opportunities shrank. In the end, under the circumstances of shortages or gaps, instructors had to bear the burden of improving the situation. These weren't isolated stories but recurring patterns, visible in primary schools and doctoral programs alike, across countries with very different levels of wealth.

Education has moved quickly into digital spaces, however, the introduction of tools such as VR, XR/AI has exposed gaps between technological ambition and the everyday practice of teaching. These gaps are not easily explained by shortages of bandwidth or hardware alone. They appear to signal a problem, tied to how pedagogy is imagined and carried out. Through collaboration across countries, combined with analysis and conversations with educators and learners, the e-DIPLOMA project uncovered systemic barriers. Such barriers influence nearly every stage of education, from how learning is conceptualized to how it is sustained within institutions.

Rather than treating VR, XR/AI as separate tools that can simply be inserted into existing routines, the project framed immersive learning as a response to structural weaknesses. The digital environment still shows signs of rigidity and a tendency to lag behind the real needs of learners. In practice, many systems risk overwhelming students with content while offering little space for interaction. The situation is made more difficult by institutional resistance to change, infrastructure that varies widely, and policies that fail to align across contexts.

<u>Cognitive, affective, and embodied learning needs.</u>

The cognitive side of learning includes various skills such as attention, reasoning, problem-solving, and self-reflection. Normally, educational institutions test these abilities through exams. Yet the relationship between digital tools and these functions is rarely straightforward. Some technologies seem to support them, but others appear to do the opposite. Much of conventional e-learning still promotes relatively superficial engagement. Learners find themselves memorizing fragments of content, often without deep reflection and no space for critical questioning or for practical application of the obtained knowledge.

According to previous research on the realities of online education during the pandemic, cognitively, remote instruction tended to flatten. A "lesson" became a recorded video, a quiz, or a PDF of exercises. These kept students occupied but rarely pushed them to challenge misconceptions, test arguments, or apply knowledge to messy, real-world cases. Some learners managed to bridge the gaps on their own, usually those with stable connections, quiet study spaces, and parental support.

Others—sharing devices with siblings, struggling with irregular internet, or working in a noisy flat—simply could not keep pace. Affective needs were just as fragile. Without quick feedback, many students began to wonder whether anyone even noticed their work. A blank Zoom room, where only a few voices spoke, could feel alienating. Those starting school in a new country or studying in a second language often feel invisible. Teacher confidence, which might sound like a side issue, proved decisive: when educators experimented with tools and carried some of their classroom energy online, students seemed to respond; when teachers felt lost or frustrated, motivation on both sides crumbled.

Embodied learning—the chance to manipulate, rehearse, or experiment—was the first casualty of the screen. Science experiments became YouTube demonstrations, practical nursing skills were postponed indefinitely, and vocational trainees were told to "imagine" the use of equipment they had never touched. Some schools mailed out small lab kits or set up limited in-person sessions, but these fixes were uneven and rarely adequate. It is striking how quickly this strand of learning disappeared, as if it were an optional enrichment rather than a core dimension. Yet for many disciplines, competence depends on safe failure, on the cycle of trying, getting feedback, and trying again.

The digital divide only deepened these cracks. A student in Berlin or Paris might expect decent broadband, while another in a rural village found her connection collapsing whenever the weather turned bad. Stories of learners climbing hills to catch a signal strong enough to upload homework are not exaggerations; they illustrate how infrastructure interacts with opportunity. Hence, immersive technologies appear to offer a shift, albeit with caveats. For instance, historical simulations allow students to move through places they are unlikely to encounter in person. In language study, virtual role-plays reduce the risk of embarrassment when mistakes are made, which may, in turn, help persistence. These experiences seem to align more naturally with higher-order thinking, embedding analysis, reflection, and decision-making into contexts that feel authentic rather than abstract.

The e-DIPLOMA project's work on competency frameworks adds weight to this interpretation. Immersive design, it suggests, cannot be reduced to the adoption of new devices or platforms. It calls for a shift in pedagogy itself, one where learners are expected to question, explore, and construct knowledge actively, rather than receive it passively. Therefore, it could be stated that policy choices are to determine whether the positive shifts are possible. Subsidies for data and device replacement, targeted investment in rural networks, and stronger quality assurance for digital tools are not just technical matters; they are education policy. Assessment and monitoring also need to change. Counting log-ins or completion rates tells us little about what students actually learned. Better indicators would track conceptual understanding, sense of belonging, and demonstrated competence in real or simulated tasks, disaggregated by background, so inequities surface before they harden.

<u>Inadequacies of existing e-learning systems.</u>

Many of the tools we now associate with online learning were not chosen because they were well-suited for the task; they were rather what was available. A video conferencing platform became a classroom. An email thread turned into office hours. For a while, this cobbled-together version of education held things together. But as the crisis phase ended, the cracks that were once hidden by urgency began to show. A central issue, one that often goes unspoken, is that most e-learning systems are built to deliver content—not to support learning in any deep or responsive way. They are excellent at tracking completion and delivering modules in order, but can be useless or insufficient to deal with unplanned interaction.

One of the most frequent limitations is constituted by the passive learning mode during a conventional e-learning system. That is because the problem gets worse when you consider how disjointed most online learning ecosystems are. One platform for watching lectures. Another for uploading assignments, a third for checking grades, and a fourth for asking questions. The promise of “modularity” often ends up feeling like fragmentation. Students are left to piece together the logic of their own education, while instructors spend an excessive amount of time navigating between platforms. It’s not uncommon for a student to miss a deadline because they weren’t sure which system it was on, or for a teacher to discover too late that a submission never went through. After all, a plugin failed. Therefore, learners who require additional support from an instructor or extra time might be left behind; at the same time, students with potential to accelerate and explore more are constrained.

Collaboration might suffer too, as peer interactions can be relegated to chat windows and fail to reproduce the dynamics of in-person learning spaces. Unlike physical classrooms with their possibility to adapt in real time with the moderation from instructors, digital course materials can be difficult to revise without technical support. This limitation may be especially visible in fast-evolving disciplines, where the need for up-to-date knowledge is pressing. Under such circumstances, both learners and instructors can find themselves immersed in obsolete case studies and datasets, which reduces their educationally relevant experience.

Technological, institutional, and cultural barriers.

One of the most visible constraints encountered in the pilots has been the hardware and connectivity deficit. Some schools lacked sufficient numbers of modern XR gadgets, or their devices were older and less capable, which affected user experience. Bandwidth limitations, network instability, and slow internet connections also disrupted immersive experiences—participants report delays, loading issues, or breakdowns in group work when connection drops. These technical frictions often forced teachers to simplify or abandon planned XR/AI tasks mid-lesson.

Another issue relates to usability and maintenance. XR/VR tools often require specific environmental conditions (lighting, space, ventilation). If the classroom lacks these or if technical support is minimal, tools degrade in usefulness. Maintenance of devices, updating firmware, keeping software licenses, and integrating tools with existing learning management systems have posed logistical challenges. Teachers often noted that when updates fail or compatibility issues arise, confidence in the tool declines.

Cognitive overload is a subtle but critical technological barrier. Immersive environments rich in sensory input can overwhelm some learners—especially younger ones or those with less digital literacy. Fatigue, disorientation, and motion sickness were reported in some pilot settings, especially when sessions ran too long without breaks or when the XR content was very complex without adequate scaffolding. The hardware itself (e.g., headset size, visibility) and interface design sometimes exacerbate these effects.

Finally, the scalability of technology is challenging. What works in a lab or small-scale pilot may fail when scaled up to many schools. Procurement of sufficient devices, ensuring uniform performance, dealing with uneven infrastructure, and supporting ongoing updates all require sustained funding and technical capacity. Without that, promising technologies risk becoming pilot curiosities rather than embedded tools.

Institutional readiness varies greatly between schools, regions, and countries. Some schools have supportive leadership, innovation labs, and dedicated personnel for tech support. Others do not. When leadership lacks vision or resources, VR,XR/AI initiatives suffer from lack of coordination, unclear roles, or patchy implementation. Teachers may be enthusiastic but without formal support—such as allocated time for training, for planning XR-oriented instruction, or for upkeep of the devices—they often end up adopting superficial or ad hoc use.

Another institutional issue is policy and strategic alignment. Projects sometimes run in isolation of district or national curricula, teacher training programs, or administrative systems. Without alignment, XR/AI tools may contradict existing assessment regimes or be poorly integrated into students' learning journeys. In e-DIPLOMA pilots, some teachers flagged that even when immersive tools were used, they didn't always map onto examination requirements or learning outcomes, which limited how much time or effort could be devoted to them.

Resource constraints are a significant barrier. Budget limitations affect not only purchase of devices, but also ongoing costs (maintenance, software licenses, technical support). In many pilot sites, lack of dedicated funding for XR/AI forced institutions to rely on external grants, short-term projects, or donations. That fragility risks making the technology's use contingent rather than sustainable.

Institutional culture also plays a role. Where risk aversion is strong, or where innovation is not part of the school's tradition, there is hesitation to try immersive tools. Teachers may fear negative consequences (e.g. losing control of class, wasting time, poor student outcomes), or feel that using new tools might not be valued in evaluation or promotion.

Culture in this context refers to beliefs, attitudes, norms, expectations, and practices of students, teachers, families, and broader society. In the e-DIPLOMA project, several cultural barriers have shown up.

One barrier is digital literacy and comfort level. Some learners and teachers come from backgrounds where technology has not been priorities by their community or administration. According to the OECD data before the pandemic crisis, fewer than 40% of educators across the EU felt ready to use digital technologies in teaching (OECD, 2018). Over 40% of 13-14-year-olds in the EU lack basic digital skills, falling short of the EU's 2030 goal of reducing this figure below 15% (ICILS, 2023). According to the International Computer and Information Literacy Study (ICILS), basic digital skills encompass far more than simply knowing how to use a device. They involve the capacity to navigate digital environments with confidence and safety, as well as the ability to assess the credibility of online information. Learners are also expected to work with standard productivity tools such as word processors and spreadsheets, communicate effectively through digital platforms, and approach problem-solving using technological resources. In essence, these skills form the foundation for meaningful participation in today's digitally connected world. When immersive or AI-tools are introduced without sufficient orientation, users feel intimidated, frustrated, or dismissive. This reduces uptake and can increase inequality between those familiar with digital tools and those less so.

Another cultural obstacle is expectations about teaching and learning. Traditional teacher-centered instruction with strict hierarchical relations between an educator and a student remains dominant in many places. Immersive experiences challenge some expectations: students working more independently, teachers facilitating rather than lecturing, more exploration rather than fixed content. In some settings, this shift is slow or resisted, especially when exam results and standardised assessments are important.

Privacy and trust concerns also reflect culture. Families or institutions may worry about how student data is used, about algorithmic decision-making in AI tools, about surveillance, or about unintended biases. In contexts where trust in institutions or technology providers is low, these worries can become strong inhibitors to adoption. Therefore, cultures that are more cautious about adapting new disruptive technologies need more time and effort directed at education about their positive potential.

Finally, there is cultural diversity and inclusion, differences in language, norms, identity, and accessibility. If VR,XR/AI content is not adapted to linguistic diversity, learner background, or accessibility needs, it can alienate or exclude. Cultural sensitivity matters: not all immersive content is neutral; some implicitly carry cultural assumptions that not all learners share.

Chapter 1. Good Practices and Ecosystem Analysis for VR/XR/AI Integration in Education

1.1 Pedagogical co-creation as an educational best practice

Among the pedagogical models informing VR/XR/AI adoption, co-creation stands out as a promising approach to foster engagement, equity, and shared ownership of learning. In immersive and digitally supported environments, co-creation can occur at multiple levels, from co-designing virtual learning scenarios to refining adaptive feedback systems through user input.

Co-creation is quite an innovative instrument for the sphere of education. Instead of institutions "delivering" education while students "consume" it, value is made together through ongoing exchanges. Students contribute study strategies, discipline-specific insights from internships, and gritty feedback about what actually helps them learn. Institutions bring curriculum expertise, infrastructure, and professional judgment. When those resources meet, courses, services, and relationships tend to change in ways that look more sensible on the ground.

This report uses a two-part frame (Dollinger et al., 2018) drawn from service theory. Co-creation has two complementary dimensions (Figure 5):

1. *Co-production* (design and delivery). This is the upstream work where students shape the value proposition itself—program structures, assessment briefs, advising processes. There are three key factors:

    - Knowledge. This allows to highlight and integrate students' perspectives and know-how.

    - Equity. This aspect helps to recognize the political dimension of education accessibility and takes into account inherent privileges and barriers.

    - Interaction. This aspect addresses the major question: is the dialogue frequent, two-way, and consequential? It seeks to preserve reciprocity and regularity of student-instructor engagement.

2. *Value-in-use* (use and experience). Value is not an inherent part of a syllabus; it rather appears when students use what has been offered to them among the available instruments. Three elements shape that lived value:

    - Experience. How does the co-designed course feel day to day? Do students report fewer "busywork" assignments and clearer pathways through a unit? This helps to follow the day-to-day learning journey.

    - Personalization. It helps to track how much the system can be adapted to individual needs and aims.

- Relationship. Do students start to describe “our department” rather than “the department”? That identification is often demonstrated in minor details: returning as mentors, flagging issues early, recommending the program to a friend.

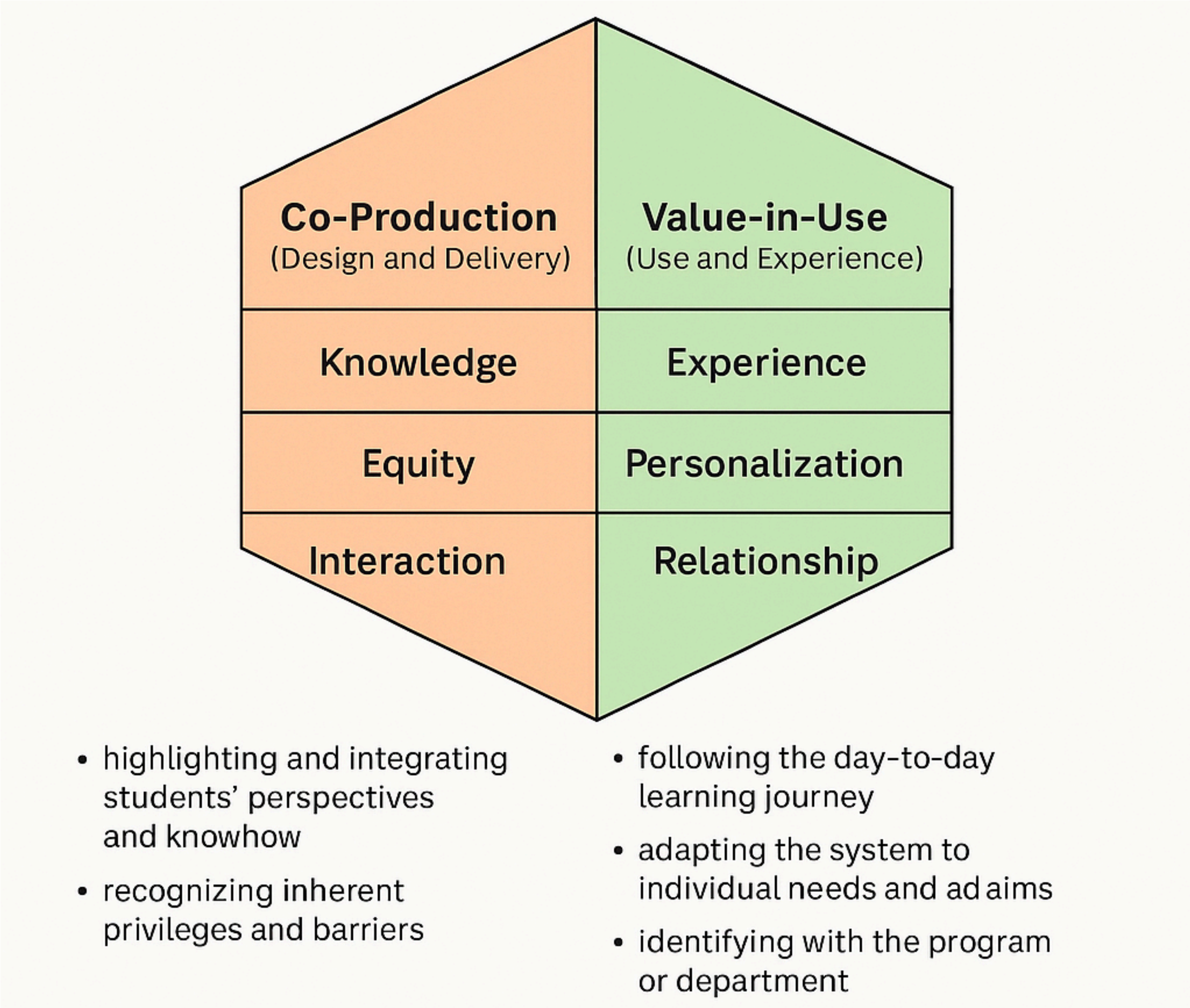


Figure 5. Dual Dimensions of Co-Creation in Immersive Education

Co-creation practices are critical for educational innovation (Bowden & D’Alessandro, 2011; Díaz-Méndez & Gummesson, 2012; Füller et al., 2011; Navarro-García et al., 2015; Elsharnouby, 2015) because education in general, including higher education, is a classic credence good. Its full value shows up later, sometimes within years and decades. Co-creation appears to narrow the information and power gaps that make the delay risky. Frequent, structured interaction surfaces problems sooner (such as a confusing prerequisite map, or the internship paperwork that might be challenging for international students), which in turn makes change more responsive.

It is important to highlight that the benefits of this approach are mutual. For students, better conversations with instructors tend to correlate with stronger engagement and satisfaction, and with the kinds of capabilities employers actually ask about-honest and open feedback, collaborative problem-solving, judgment under time pressure. For educational institutions, co-creation is likely to support loyalty, strengthen the institution's image, and deepen student-university identification. Alumni who felt heard as students often keep showing up: giving talks, opening doors, or funding a scholarship. This is not guaranteed, however, the pattern is visible enough to be considered from serious perspective.

WP2 evidence shows that institutions face uneven infrastructural, normative, and personal capacities for VR/XR/AI, and that staff and students perceive readiness differently; co-creation helps surface those constraints early and adapt designs accordingly. At the same time, D.2.1 warns that piling up multimodal features can overshoot learners' cognitive bandwidth—co-design must therefore balance ambition with cognitive ergonomics.

It is important to note that co-creation should not be perceived as a silver bullet or a tool capable of resolving any issue. Unfortunately, the accumulated experience in recent years shows that it can slow decisions, expose conflict, and surface trade-offs we'd rather leave hidden. It may also redistribute status—away from traditional gatekeepers and toward students who articulate needs we hadn't prioritized. The idea of co-creation shows how teaching and learning can become a shared process rather than something designed and delivered from above. The next sections translate this principle into documented best practices and policy-relevant lessons from WP2. It looks at concrete examples of how schools and universities have already begun to translate these participatory ideas into real strategies, in classrooms, curricula, and policies, that make digital transformation work. Through these cases, we can see how the spirit of collaboration behind co-creation takes shape in the everyday use of VR, XR, and AI tools across different educational contexts.

1.2 Evidence base and methodology

This chapter aims to identify, examine, and contextualize best practices that may inform policy decisions on the integration of VR, XR, and AI technologies in education. Positioned toward the conclusion of the strategic recommendations, its role is not simply to celebrate successful experiments but to translate them into practical, adaptable, and context-sensitive insights. These cases may serve as reference points or inspiration for institutions, educators, and policymakers attempting to design, scale, or refine their own digital transformation pathways.

The methodological approach followed in preparing this chapter draws primarily on the Best Practices Report (D.2.1), which catalogues international examples of VR, XR, and AI applications in education, spanning diverse levels of implementation and institutional types. Complementing this, the *Initial Analysis Conclusions (D.2.2)* consolidated findings from literature reviews, values workshops, and a multi-country capacity survey. It provided a structured lens on four dimensions of institutional capacity (infrastructural, normative, cultural, and personal) that influence readiness for VR/XR/AI integration. These insights helped contextualize the pedagogical and systemic challenges discussed later in this chapter. Instead of simply extracting models to be replicated, the analysis seeks to understand the contextual parameters, pedagogical choices, and technological conditions that shaped these practices. The value of combining structured, theory-informed frameworks with grounded, real-world experimentation lies in the potential to highlight not only what was successful but also what appears to have made success more likely. In many cases, success was not immediate nor linear, and even in high-performing examples, trade-offs and tensions were present.

The analysis did not aim to extract ready-made models to be replicated but to identify patterns, contextual factors, and enabling conditions that make innovation sustainable. By comparing international evidence with e-DIPLOMA experiences, it was possible to highlight the pedagogical, technological, and governance mechanisms that contribute to meaningful digital transformation.

The following sections (1.3.1–1.3.5) present the main findings derived from this combined evidence base, organized around five interrelated dimensions: strategic integration, infrastructure and ecosystems, pedagogical models, capacity building, and ethics and inclusion. Together, they form a set of lessons and directions that can inform future policy and practice at institutional, regional, and European levels.

1.3 International Best Practices in XR/AI-Enhanced Education

1.3.1 Strategic Integration of VR/XR/AI in Curricula

The integration of VR, XR and AI technologies into educational curricula appears to be most impactful when it is aligned with national or regional digital transformation strategies. Across the examples documented in the Best Practices Report, the presence of supportive policy frameworks seems to function as a critical enabler. These frameworks do not necessarily dictate uniform solutions, but they often provide direction, infrastructure support, and legitimacy, making experimentation at the institutional level more feasible.

In several cases, the adoption of VR/XR/AI was catalyzed by overarching strategies aimed at increasing the digital maturity of public education systems. For instance, digital education action plans or innovation roadmaps at the national level have, in some contexts, provided schools and universities with funding, technical assistance, and access to cross-sector partnerships. While not all institutions moved at the same pace, those situated within such supportive ecosystems were more likely to pursue VR/XR/AI integration as a strategic priority rather than an isolated project.

At the institutional level, the practices observed suggest that sustainable implementation rarely stems from standalone pilot projects. Instead, more promising outcomes tend to emerge when VR, XR, and AI are gradually embedded into curricular structures, teaching practices, and organizational planning. Some institutions have created dedicated innovation hubs or interdisciplinary task forces to support this process. These units often operate as connectors, linking pedagogical needs with technological developments and facilitating internal knowledge sharing.

WP2's institutional capacity scan shows that strategic integration depends on four capacity blocks (infrastructure; normative/regulatory; teaching culture; personal competencies), with uneven readiness across contexts—useful to interpret why aligned strategies scale better. Notably, institutional strategies appear to vary widely depending on existing capacities, leadership commitment, and access to funding. Some universities have leveraged public-private partnerships to build custom XR platforms, while others have opted to embed immersive tools within existing Learning Management Systems. The choice of model seems to be influenced not only by budget constraints but also by pedagogical philosophy and governance structures.

It is also worth noting that institutions with more mature strategies tend to invest in capacity-building alongside technical implementation. Rather than focusing exclusively on acquiring equipment or licenses, they also consider curriculum redesign, teacher training, and student readiness as part of the same transformation effort. This systemic orientation may not guarantee success, but it does seem to correlate with longer-term sustainability.

In addition, integration is more effective when it involves deliberate curriculum mapping. Several best practice cases point to the value of identifying specific competencies, subjects, or learning scenarios where XR or AI can create tangible pedagogical benefits. Without this curricular alignment, there is a risk that technological adoption remains peripheral, driven more by novelty than by meaningful educational goals.

While the evidence gathered in the Best Practices Report cannot offer a single blueprint for integration, it does suggest that strategic alignment—across policy, institution, and curriculum—creates conditions under which VR/XR/AI can be used not just as tools, but as catalysts for pedagogical innovation. Importantly, this alignment is not a static achievement. It requires ongoing negotiation between stakeholders, adaptation to emerging technologies, and sensitivity to the diverse contexts in which learning takes place.

Table 14. Strategic Conditions Enabling VR/XR/AI Integration in Curricula

Level	Key Enabling Factors	Examples and Insights
Policy Level	• National/regional digital education strategies • Funding and infrastructure support • Legitimacy	• Digital action plans provide direction • National frameworks catalyse institutional adoption
Institutional Level	• Innovation hubs or task forces • Public-private partnerships • Governance and leadership commitment	• Internal units facilitate tech-pedagogy linkages • Strategies vary based on leadership and capacity
Curricular Level	• Curriculum mapping to align with competencies • Gradual integration into teaching practices	• Specific subject areas identified for VR/XR/AI use • Avoids superficial adoption driven by novelty
Capacity Building	• Teacher training • Curriculum redesign • Student readiness initiatives	• Sustainable integration includes investment in people, not just tools
Sustainability Factors	• Systemic orientation • Adaptation to local conditions • Continuous stakeholder dialogue	• Long-term success tied to flexibility, not rigid blueprints

1.3.2 Infrastructure and Technological Ecosystems

The physical and digital infrastructure underpinning VR, XR, and AI implementation in education appears to play a decisive role in determining both the scale and the sustainability of innovation. Institutions that have succeeded in developing XR-integrated learning environments often benefit from an ecosystem that is not limited to hardware or connectivity alone, but one that incorporates spatial design, maintenance strategies, and access to expert technical support.

Several best practice cases reveal how immersive classrooms and XR labs have emerged not as isolated installations, but as hubs embedded within broader educational ecosystems. For instance, some schools and universities have established flexible, modular spaces equipped with 360° projection systems, motion tracking, and VR headsets. However, these spaces are rarely treated as ends in themselves. Their value often depends on how well they are integrated into everyday teaching routines and whether they are supported by clear usage protocols and scheduling mechanisms. Without these operational foundations, even technically advanced environments can become underused or misaligned with pedagogical goals.

Particularly in publicly funded institutions, infrastructure development tends to be shaped by access to external partnerships. Collaborations with regional technology clusters, university spin-offs, or educational technology providers have proven instrumental in some of the documented cases. In certain instances, public-private partnerships have facilitated access to emerging XR platforms or enabled co-design processes for tailored solutions. Yet these partnerships also introduce questions about procurement, intellectual property, and long-term service provision, which institutions must manage proactively.

A key insight from the Best Practices Report concerns the value of ecosystem thinking. Institutions that frame infrastructure not merely as a procurement task, but as a multi-actor, iterative process, appear better positioned to adapt to evolving technologies. Survey data indicate infrastructures are mostly experimental rather than at-scale, and costs/FAIR/sustainability constraints complicate resource sharing—hence the value of pooled or shared-service models. For example, some schools participating in national innovation networks have been able to upgrade or diversify their equipment thanks to pooled funding mechanisms or shared service models. This collective approach may not resolve all resource constraints, but it does offer a pathway for smaller or less affluent institutions to participate meaningfully in digital transformation efforts.

At the same time, technical readiness alone does not guarantee educational value. Several examples highlight how institutional planning often involves parallel efforts to ensure interoperability between new VR/XR/AI tools and existing learning management systems, assessment platforms, or digital repositories. Without such compatibility, even well-equipped environments can fragment learning experiences and create barriers for teachers or students navigating multiple systems.

Finally, the notion of technological ecosystems extends beyond the boundaries of any single institution. In certain regional contexts, education authorities or innovation agencies have begun to support infrastructure deployment through targeted funding calls, open-source toolkits, or advisory services. These top-down initiatives may accelerate access, but they require sustained coordination with the ground-level actors who actually implement, maintain, and adapt the technology over time.

In sum, while infrastructure is often perceived as a technical challenge, the most effective models appear to treat it as a relational and strategic domain. Success is rarely measured by the sophistication of the hardware alone, but by how flexibly and equitably it serves the evolving needs of learners, educators, and communities.

1.3.3 Pedagogical Models and Instructional Design

The integration of VR, XR and AI into education does not automatically yield innovative learning outcomes. Much depends on the underlying pedagogical frameworks and the capacity of institutions to redesign instruction in alignment with new technological possibilities. Several best practices illustrate that meaningful digital transformation in education appears to hinge less on the presence of advanced tools and more on how these tools are orchestrated within pedagogical strategies. The D.2.1 analysis associates higher knowledge gains with designs that increase sensory channels, clarify learning effects, and stage experiential phases—evidence you can use to prioritize design levers in practice.

A recurring element in the cases analyzed is the move toward **competency-based learning environments**, where knowledge acquisition is demonstrated through performance and application, rather than measured solely by time or test scores. In some instances, XR technologies have enabled learners to engage with abstract concepts through multisensory experiences, such as exploring architectural principles by walking through virtual buildings or simulating biological systems in 3D environments. These immersive approaches may allow for deeper engagement, particularly for students who struggle with conventional didactic formats. Yet, their effectiveness seems contingent on structured scaffolding, guided reflection, and clear alignment with learning objectives.

Another observation relates to the **flexibility of lesson formats**. XR, when thoughtfully designed, appears to support experiential learning pathways that extend beyond the confines of traditional classroom layouts. In several cases, educators have created micro-modules that allow students to progress at their own pace within virtual environments, pausing, repeating, or accelerating based on their needs. These experiences were often framed within broader inquiry-based or project-based approaches, offering learners greater control over their own learning trajectories.

Artificial Intelligence tools have also started to play a formative role in reshaping instructional design. In some best practice examples, AI-driven systems have been used to monitor learner progress and adapt the level or form of content delivery accordingly. This form of **adaptive learning** can potentially increase inclusivity by responding to individual needs. However, the evidence also points to important caveats. The personalization afforded by AI is only beneficial when it aligns with clearly articulated pedagogical intentions and when educators remain actively involved in interpreting and adjusting the automated suggestions.

The report further notes that without careful integration, these new approaches may unintentionally reinforce existing inequalities. For example, learners who are less familiar with digital environments may benefit less from self-paced, AI-guided instruction unless they receive appropriate orientation and support. Similarly, the immersive nature of XR may not suit all learners unless options for differentiated participation are built into the lesson structure.

What emerges from these insights is that technology-enhanced pedagogy works best when developed collaboratively. In several cases, lesson design was not left to individual educators alone but involved multidisciplinary teams that included instructional designers, XR developers, and subject-matter experts. This co-design model seems to increase both the usability and the educational value of the resulting materials, although it demands significant coordination and institutional support.

Ultimately, while VR, XR and AI open new pedagogical horizons, their transformative potential depends on how carefully they are mapped onto coherent instructional strategies. As institutions continue to explore these possibilities, the most promising practices appear to be those where experimentation is coupled with critical reflection, and where innovation is grounded in clear educational purposes rather than technological novelty.

Table 15. Pedagogical Enablers and Conditions for VR/XR/AI Integration

Component	Description	Observed Practices and Implications
Competency-Based Learning	Emphasizes performance, application, and experiential learning	• XR used for simulating environments (e.g., virtual buildings, biology systems) • Requires structured scaffolding and alignment with learning goals
Flexible Lesson Formats	Modular and self-paced pathways through XR environments	• Micro-modules enable pausing and repetition • Often combined with inquiry-based or project-based models
Adaptive Learning via AI	AI systems adjust content based on learner behavior and progress	• Promising for personalization • Effectiveness depends on educator oversight and pedagogical coherence
Support for Diverse Learners	Differentiated options to accommodate varying digital literacies and learning styles	• Digital orientation and inclusive design needed • XR may overwhelm without careful structuring
Collaborative Lesson Design	Co-creation between educators, developers, and designers	• Multidisciplinary design teams improve usability and relevance • Requires institutional support
Critical and Reflective Integration	Pedagogical goals drive tech use—not novelty or tool availability	• Most effective when innovation is purpose-driven • Reflection embedded in instructional planning

1.3.4 Capacity Building and Teacher Training

The success of VR, XR, and AI integration in education may ultimately depend less on the technology itself and more on the people who use it. Across various best practice cases, it becomes apparent that educators often serve as the primary bridge between digital innovation and meaningful learning. However, introducing new tools into classrooms—particularly those as complex as immersive or AI-powered systems—requires a rethinking of traditional professional development approaches.

Many institutions reported difficulties in motivating staff to engage with unfamiliar technologies, particularly when training was limited to one-off workshops or narrowly focused technical sessions. By contrast, those cases that managed to create sustainable models of capacity building often relied on ongoing, embedded forms of professional learning. Rather than being treated as an isolated phase, training was framed as an evolving process, closely tied to educators' everyday pedagogical work. Participants were encouraged to experiment incrementally, reflect on their practice, and adapt new tools according to their local context. This approach appears to offer not only more sustainable outcomes but also greater emotional engagement and ownership. In several initiatives reviewed, capacity-building activities were closely linked to peer-to-peer learning structures.

In several initiatives reviewed, capacity-building activities were closely linked to peer-to-peer learning structures. Teachers with early experience in VR, XR, or AI were invited to act as internal mentors or facilitators, offering guidance to their colleagues and helping contextualize abstract technical ideas through classroom-relevant examples. In some instances, formal mentoring programs were established, with more experienced staff co-designing lessons or co-teaching sessions alongside less confident peers. These horizontal knowledge flows may help reduce resistance to change and support gradual adaptation rather than abrupt transformation.

One particularly effective model that surfaced in the analysis involved integrating digital pedagogies into initial teacher education. Rather than postponing training until after educators enter the workforce, several universities embedded VR, XR, and AI use into pre-service curricula, enabling student teachers to acquire fluency with these tools early on. This not only reduced anxiety around digital innovation but also appeared to shape more critical and reflective attitudes toward technology. Still, the degree to which this practice is widespread remains limited, and its long-term effects on teaching practice have yet to be fully understood.

What also emerges is the importance of multidisciplinary in training programs. In a number of successful examples, teachers were not trained solely in how to operate VR/XR devices or interact with AI platforms. They were also invited to consider broader questions—ethical, pedagogical, and cognitive—that surround the use of such tools in education. Training sessions included sessions on inclusive design, attention management in immersive settings, and the risks of algorithmic bias. This richer framing may increase educators' sense of responsibility and agency in shaping how VR, XR and AI are deployed, rather than positioning them merely as users of ready-made systems.

Nevertheless, some limitations persist. Time constraints, lack of institutional incentives, and uneven digital infrastructure often pose serious barriers to teacher participation in training programs. Even in well-resourced settings, teachers may find it difficult to keep up with the pace of technological change without institutional commitment to long-term professional development pathways.

Overall, the evidence suggests that effective capacity building is not just about delivering technical knowledge. It appears to involve fostering supportive learning cultures, encouraging experimentation, and acknowledging the diverse entry points from which educators approach technology. As VR, XR and AI continue to evolve, training programs will need to remain agile, reflective, and deeply rooted in the lived realities of teaching practice.

1.3.5 Ethics, Inclusion, and Accessibility

The integration of VR, XR, and AI into education brings significant opportunities, yet it also raises ethical and accessibility concerns that cannot be dismissed as secondary. Across the best practices examined, there is a growing recognition that technological innovation must be balanced with principles of fairness, transparency, and inclusion. This awareness, while not always embedded structurally, appears to be shaping a new layer of institutional responsibility.

Several documented cases have made early steps toward more inclusive practices, particularly when designing XR applications for students with disabilities. These efforts often go beyond superficial accommodations. In a few notable examples, content creators worked in collaboration with special educators and accessibility experts to rethink spatial navigation, adjust visual load, and offer multiple modes of interaction. Text alternatives, haptic feedback, and voice commands were used not merely as optional features, but as central design considerations. Still, the extent to which such practices are standardized remains uneven, and many initiatives acknowledge that universal accessibility remains aspirational rather than fully realized. Values workshops repeatedly surfaced accessibility, adaptability, autonomy, trust, control, and surveillance across scenarios, so inclusion work must go beyond devices to cognitive load, consent, and bias.

When it comes to governance and ethical oversight, the analysis suggests a fragmented landscape. While some institutions appear to have adopted internal frameworks for data protection and AI governance, these mechanisms are often reactive rather than anticipatory. There are cases where data privacy protocols have been clearly articulated, particularly in relation to student profiling and automated feedback systems. However, the capacity to audit algorithmic decisions or track unintended consequences remains limited in most cases. Institutions often depend on third-party providers for AI solutions, which complicates issues of transparency and accountability.

Interestingly, a few best practice cases show that inclusive and ethical design can emerge more strongly in interdisciplinary teams. When educators, IT developers, legal experts, and students collaborate during the development phase, questions around bias, consent, and access are more likely to be addressed proactively. This approach, however, is still more the exception than the rule. Many projects appear to rely on the goodwill or individual interest of staff, rather than embedding such practices into institutional policy.

Another challenge that appears to recur is the limited representation of vulnerable learners in the design and testing phases of VR/XR/AI tools. While some projects conducted focus groups or user testing with diverse participants, these efforts were often isolated and lacked continuity. As a result, even when design principles aimed at equity were identified, they were not always translated into lasting design changes or documented as institutional knowledge.

In terms of systemic approaches, a handful of national frameworks reviewed in the report do include references to ethical AI and digital inclusion, but operationalization varies. Where inclusion is addressed, it tends to focus on infrastructure (e.g., broadband access or device availability), rather than the less visible but equally important layers of accessibility—such as cognitive load, cultural sensitivity, or emotional safety in immersive environments.

What seems to emerge from this body of practice is a shared understanding that ethics and inclusion are not ancillary to innovation, but foundational to its legitimacy and effectiveness. However, the translation of this understanding into actionable models remains a work in progress. Efforts are being made, and some institutions appear to be moving from reactive compliance toward more proactive governance and design, yet the field still lacks robust standards and shared benchmarks.

As VR, XR and AI become more embedded in educational ecosystems, the demand for clarity, transparency, and accountability is likely to intensify. Institutions may need to establish not only technical safeguards, but also cultivate a culture of reflection and ethical sensitivity among staff. Only then can digital transformation truly serve the full spectrum of learners it promises to empower.

1.4 Competency-Based Frameworks and Learning Evaluation for VR/XR/AI Integration

The rapid growth of Virtual Reality (VR), Extended Reality (XR), and Artificial Intelligence (AI) is pushing education into unfamiliar territory. These technologies are not simply add-ons to existing practices; in some cases, they force institutions to reconsider how learning is structured, assessed, and even certified. Competency-Based Education (CBE) has been taken up as one possible response, as it shifts the focus from fixed timetables to what learners can actually demonstrate. Advocates suggest that such a model is better suited to a world where both technologies and labor markets change quickly and unpredictably (Levine & Patrick, 2019).

CBE is often described as allowing students to move at their own pace by proving mastery of knowledge, skills, or attitudes in applied contexts rather than sitting through standardized lessons (Sturgis, 2012; Curry & Docherty, 2017). In theory, this aligns well with VR, XR, and AI. Virtual environments can place learners in situations that feel close to professional practice, while AI systems can monitor patterns of progress and adjust feedback in real time. Yet in practice, questions remain. Not every competency translates smoothly into a simulation, and institutions still struggle with what counts as “enough evidence” of mastery.

The literature also shows that the basic vocabulary of CBE is contested. Terms such as competence, proficiency, qualification, and skill are sometimes used interchangeably, sometimes treated as distinct, and often left undefined (Evans et al., 2021). This lack of clarity is more than a theoretical nuisance. Without shared definitions, designing assessments or aligning policies becomes difficult, and learners may not trust the value of alternative credentials.

Integrating CBE with VR, XR and AI complicates matters further. Immersive environments can support embodied and situated learning, but they also blur the line between practice and performance. AI analytics promise granular feedback, yet they raise concerns about fairness and the potential loss of human judgment (Ford, 2014; Rainwater, 2016). What looks like personalization from one perspective can appear as surveillance from another.

Evaluation, then, cannot be reduced to dashboards or slightly modified rubrics. It involves a deeper shift: moving away from one-off tests and towards ongoing observation of learning in context. Some researchers have even argued for “learner profiles” that combine data from multiple sources—simulation logs, collaborative interactions, reflective journals—to capture development over time. These ideas are attractive, but the risk of overcomplication and data overload is real.

Sturgis and Casey (2018) argue that traditional education has long privileged ranking over genuine comprehension. CBE, particularly when paired with VR, XR, and AI, holds out the possibility of doing better—making learning more personalized and, ideally, more equitable. But whether this promise is realized depends less on the tools themselves than on how institutions interpret them, and on whether educators and learners feel they are partners in the process rather than subjects of an experiment.

Yet the potential of CBE depends heavily on how it is designed and enacted. Many hinges on whether competencies are defined in ways that make sense for particular contexts, and whether assessments are genuinely tied to the kinds of learning activities that precede them. The use of AI-driven analytics can extend possibilities for feedback, but only if it is handled inclusively and with attention to ethical safeguards (Torres et al., 2015). Just as important, institutions need mechanisms to adjust their frameworks over time, drawing on evidence from learners' actual experiences rather than on abstract models.

There is also a cautionary note. When reduced to nothing more than a checklist of outcomes, or when evaluation is handed over wholesale to algorithmic systems, CBE risks losing its radical edge. What should serve as a flexible, learner-centered approach can easily slide into another layer of bureaucracy, one that constrains teachers and students alike instead of opening new pathways for learning (Curry & Docherty, 2017).

This chapter engages with these tensions and opportunities by presenting a framework for competency-based learning evaluation tailored specifically to VR, XR, and AI-enhanced educational environments. Drawing on recent empirical studies, conceptual clarifications, and emerging best practices, it addresses three interrelated questions:

1. **Which digital and socio-emotional competencies should be prioritized** in VR/XR/AI-mediated learning, and how should they be contextualized in domain-specific curricula?

2. **What types of assessment tools and evidence** are appropriate for capturing meaningful learning in immersive and adaptive environments?

3. **How can institutions develop valid, ethical, and actionable metrics** that go beyond legacy indicators to capture learning progress, engagement, and mastery in real time?

By reconceptualizing competence as a dynamic capacity for *autonomous, responsible, and context-sensitive application of knowledge and skills*, and by embedding this reconceptualization in the affordances of VR, XR, and AI, we aim to articulate a framework that supports learning that is not for compliance, but for life.

1.4.1 Targeted digital and socio-emotional competencies

The arrival of Virtual Reality, Extended Reality, and Artificial Intelligence in education is unsettling long-held assumptions. It is no longer just about "delivering content" and then testing whether students remember it. The emphasis is shifting, sometimes awkwardly, towards what learners can actually *do* in contexts that are often messy and unpredictable. Competence, in this sense, is not a neat list of skills. It is closer to being able to act responsibly when things don't go according to plan, or to adapt when the rules are unclear, which is often the case in immersive settings.

CBE (Competency-Based Education) is one way of thinking about this. In principle, it allows learners to move forward when they can show mastery, whether in the real world or in a simulated one. But in practice, the picture is uneven. A biology student dissecting a virtual frog may come away with a very different sense of competence than an engineering student wrestling with a malfunctioning sensor in XR. And even then, what counts as "mastery" is still open to debate. Some institutions treat it narrowly, like checking boxes on a rubric, while others experiment with more open-ended demonstrations.

Understanding Competence in VR/XR/AI Environments

In VR/XR/AI contexts, competence stretches beyond technical ability. Students need to recognize when they are out of their depth, to interpret feedback that may be automated and imperfect, and to think about the ethical side of their decisions. These environments are not neutral. A headset freezing halfway through a simulation can derail learning, and an AI recommendation that pushes one student ahead may feel unfair to another.

Simulations can also stir emotions. A disaster-response scenario, for example, can trigger stress even when everyone knows it is "just virtual." AI tools complicate this further by tailoring pathways in ways that feel opaque. One student might welcome the personalization, another might see it as intrusive. Roles also shift quickly: sometimes the learner observes, participates, and occasionally even co-designs the task, with little clarity on boundaries. Competence here is less about ticking predefined boxes and more about coping with ambiguity, even contradiction.

Digital Competencies in Context

Digital competence is often narrowly defined as the ability to operate devices or navigate software platforms. In the context of VR, XR, and AI, however, digital competence requires a broader and deeper understanding of how digital systems shape learning, interaction, and identity.

The most relevant digital competencies include:

- **Understanding Algorithmic Mediation**: Learners must be able to recognize how AI systems filter, prioritize, and respond to their behavior. This includes questioning the assumptions embedded in personalization systems and being able to detect bias in content delivery or assessment.

- **Navigating Immersive Environments**: XR settings often rely on spatial and interactive cues rather than linear content. Competence involves interpreting these cues, engaging creatively with immersive narratives, and making decisions that reflect understanding of both the environment and the intended learning outcomes.

- **Managing Digital Presence**: Learners are increasingly represented by data traces, avatars, and interaction histories. Competence here includes the ability to manage one's own representation, maintain agency in mediated spaces, and protect one's digital identity.

- **Evaluating Information in Context**: In environments that blur the boundaries between simulation and reality, learners must be able to assess the credibility and relevance of information. This includes understanding the source, context, and purpose of digital content encountered during the learning process.

- **Engaging with Interoperable Systems**: Many VR, XR and AI tools are integrated across platforms and devices. Competence involves not only knowing how to operate these systems, but also understanding how they interact, how data is shared across them, and how this impacts learning.

Digital competence is demonstrated through performance. The learner must show an ability to apply knowledge in ways that are context-sensitive and goal-directed, rather than simply completing tasks correctly.

1.4.2 Socio-Emotional Competencies in Technologically Mediated Learning

While digital environments may seem to emphasize cognitive and technical skills, the emotional and interpersonal dimensions of learning become even more important when interactions are mediated by technology. Learners must develop the capacity to understand themselves and others, to adapt to novel social situations, and to respond appropriately to feedback and failure.

Key socio-emotional competencies include:

- **Empathic Engagement**: Immersive simulations often place learners in situations that challenge their values or assumptions. Competence involves the ability to engage with other perspectives, to experience empathy, and to reflect critically on the emotional impact of those experiences.

- **Tolerance for Uncertainty**: VR, XR, and AI tasks arrive without a single "right" path, or the path breaks midway when a headset drops tracking or an adaptive system changes the prompt. Some learners freeze; others tinker. Progress here looks like small moves: pausing, naming the confusion, trying a different tactic, asking for help before frustration hardens into avoidance.

- **Collaborative Flexibility**: Teams now include peers and, at times, an AI agent that proposes fixes no one fully trusts. Coordination becomes a socio-emotional skill: reading tone in chat, deciding whose suggestion to try first, repairing attention after a false start, admitting when the tool is steering the group rather than serving it.

- **Metacognitive Regulation**: Learners who can notice how their emotions are steering decisions—speeding up, cutting corners, or, conversely, over-checking everything—are better able to reset. Simple practices help: a quick verbal check-in, a two-line note on what worked and what did not, and revisiting feedback after the heat of the task has passed.

- **Ethical and Civic Awareness**: As learners interact with systems that collect data and shape perceptions, they must understand the ethical implications of their actions. XR scenarios and AI tutors collect traces of behavior. Who sees them? For how long? What counts as consent when the default is opt-in by design? Acting competently includes asking whether an efficient choice is also a responsible one, and knowing when to say no.

These competencies emerge over time and are often developed through authentic learning experiences that require learners to respond to real or simulated challenges. They cannot be acquired through exposure alone. Structured support, reflection, and formative feedback are essential for learners to internalize and apply socio-emotional skills.

1.4.3 Integration of Competencies in Practice

In VR/XR/AI-enhanced education, digital and socio-emotional competencies are not separate domains. They interact in complex ways. For example, a learner who is technically proficient in navigating a virtual environment may still fail to collaborate effectively if they lack interpersonal sensitivity or self-awareness. Similarly, ethical judgment in a data-driven system depends not only on understanding the technical architecture but also on being able to reflect on the social impact of decisions.

For this reason, competency frameworks should avoid treating these areas as isolated skill sets. Instead, they should articulate how various competencies support each other and how they contribute to successful performance in specific learning contexts. Performance-based assessments, reflective tasks, and feedback from both human and machine agents can help make these connections visible.

It is essential to describe competencies in ways that are both specific and adaptable. Overly vague formulations such as "digital skills" or "emotional intelligence" do little to guide curriculum design or assessment. On the other hand, rigid taxonomies may fail to account for the diversity of learners and learning environments.

Competency descriptions should be grounded in observable behaviors and linked to meaningful outcomes. For example, instead of stating that learners should "use immersive tools," a more useful formulation might be: "Learners can interpret spatial narratives in VR environments and make informed decisions that align with scenario objectives." This level of clarity helps educators identify learning gaps, design effective interventions, and evaluate progress.

A key principle of CBE in VR/XR/AI integration is the recognition of learners as active agents in their own development. This principle shapes both the definition of competencies and the methods used to cultivate them. Rather than following a linear path or responding passively to system prompts, learners must engage critically with content, co-create meaning, and take ownership of their learning journey.

Framing learners in this way has practical implications. It encourages the design of experiences that require initiative, reflection, and judgment. It also positions learning as a continuous process that extends beyond the classroom or platform, into professional and civic life.

1.4.4 Assessment tools and measurable learning outcomes

Assessment in competency-based learning environments enhanced by Virtual Reality, Extended Reality, and Artificial Intelligence must reflect more than the accumulation of knowledge. It should provide robust, contextual, and often individualized insights into a learner's ability to apply competencies in complex, evolving situations. The traditional reliance on summative evaluations, standardized testing, and isolated performance metrics is insufficient when learning is immersive, nonlinear, and adaptive. In technologically mediated educational settings, assessment is not a concluding stage of learning but an integrated, continuous, and formative process that guides both learners and educators toward meaningful progress.

Competency-based education (CBE) prioritizes demonstrable mastery over time spent in class or the quantity of instructional input received. For this reason, assessment tools must be designed to capture depth of understanding, skill transferability, socio-emotional development, and decision-making under conditions that simulate real-world complexity. These goals are not easily met using conventional tools. They require a diversified and dynamic approach to assessment that can adapt to the architecture of VR/XR environments and the feedback capabilities of AI systems.

The defining feature of assessment within CBE is its emphasis on what learners can do with what they know. This perspective shifts the focus from content recall to performance in context. Assessments must elicit evidence of mastery, not merely signal familiarity with terminology or completion of tasks. In immersive environments, this often involves learners demonstrating their competencies through simulations, scenario-based tasks, collaborative projects, or guided problem-solving exercises.

Assessment in this context serves multiple purposes. It evaluates performance, informs instructional decisions, identifies learning gaps, and motivates learners by making progress visible. These multiple functions require a layered assessment strategy, combining real-time formative feedback with well-designed summative checkpoints.

1.4.5 Key Characteristics of Effective Assessment in VR/XR/AI Learning

Effective assessment tools in VR/XR/AI-enhanced CBE systems are grounded in the following characteristics:

- **Authenticity**: Tasks must mirror real or plausible professional or civic situations, allowing learners to engage with problems that are meaningful and situated in context. For example, a student in a virtual health simulation must demonstrate both technical procedures and empathetic communication with a virtual patient, revealing both cognitive and affective dimensions of learning.

- **Observability**: Performance must be observable, either through behavioral data tracked by AI or through recorded interactions in VR/XR environments. This ensures that feedback is grounded in specific actions and decisions rather than inferred from static outputs.

- **Repeatability and Adaptivity**: The system must allow learners to revisit challenges and reflect on previous decisions. VR/XR platforms that can generate variable scenarios offer the opportunity for learners to improve through iteration rather than experience a single-point evaluation.

- **Feedback Integration**: Assessment must support formative feedback loops. Whether generated by educators, peers, or AI agents, feedback should be timely, actionable, and aligned with clearly defined learning outcomes.

- **Transparency and Fairness**: Learners must understand how their performance is evaluated and how they can improve. This requires rubrics, benchmarks, or success criteria that are clearly articulated and tailored to the environment.

The Role of AI in Assessment

AI-powered assessment tools offer new opportunities for tracking progress and generating insights. These systems can analyze patterns in learner behavior, offer adaptive challenges, and provide feedback based on real-time performance data. Unlike traditional assessments that rely on predetermined answers, AI-driven tools can evaluate open-ended responses, spoken language, gesture, navigation choices, or problem-solving strategies within XR simulations.

Natural Language Processing (NLP) tools can evaluate learners' verbal explanations or written reflections, identifying misconceptions, measuring the depth of understanding, or tracking improvement over time. Computer vision systems in XR environments can monitor eye movement, gesture accuracy, or interaction patterns, providing data that would otherwise be difficult to collect at scale.

However, the integration of AI in assessment must be carefully designed to avoid biases and ensure ethical handling of personal data. Learners must be made aware of what data is being collected and how it will be used. Moreover, educators should not rely entirely on algorithmic judgment but should use AI-generated insights as part of a broader assessment strategy that includes human interpretation and dialogue.

Structuring Measurable Learning Outcomes

For assessment to function effectively within a competency-based model, learning outcomes must be formulated in a manner that lends itself to both interpretation and measurement. Vague or overly general goals such as “understand digital tools” or “improve communication skills” do little to guide assessment design. Learning outcomes should specify the behavior, the condition under which it is performed, and the criteria for success.

For instance, rather than stating that a learner should "collaborate effectively in virtual environments," a measurable outcome would specify that "the learner participates in a multi-user XR task by contributing relevant information, responding to peer inputs, and coordinating actions to complete a shared goal." This level of specificity allows the use of both automated and human assessments to track competence development.

Well-structured outcomes should be:

- **Aligned with competencies**: Outcomes should reflect the broader capabilities learners are expected to demonstrate, not merely discrete skills.

- **Context-sensitive**: Outcomes should reflect the actual learning environment and the affordances of VR/XR/AI technologies.

- **Scalable**: Outcomes should support assessment across a range of scenarios, difficulty levels, and learner profiles.

- **Progressive**: Outcomes should allow for varied levels of mastery, from foundational performance to expert application, enabling educators to track longitudinal development.

In XR environments, the conditions and tasks in which learning outcomes are demonstrated can be tightly controlled and varied. This allows educators to explore the depth and flexibility of competence rather than simply confirming that a learner has completed a task once under optimal conditions.

Integrative and Multimodal Assessment Strategies

Competency-based assessment in immersive and AI-driven learning settings must use a combination of tools to build a valid and comprehensive profile of learner development. These tools may include:

- **Scenario-based simulations**: Learners are placed in complex, time-bound situations where they must apply multiple competencies simultaneously. Their actions and decisions are recorded and analyzed to determine patterns of competence and areas for improvement.

- **Reflective narratives**: Learners articulate their reasoning, choices, and learning processes. These narratives can be evaluated using rubrics or supported by AI-based textual analysis.

- **Peer and self-assessment**: These provide additional perspectives on learner performance and promote metacognitive awareness. They are particularly effective when guided by structured prompts and anchored to shared criteria.

- **Embedded analytics**: Learner interaction data in VR, XR and AI systems can be translated into performance indicators. For example, frequency and type of tool use, decision paths taken during simulations, or persistence in the face of failure may serve as evidence of engagement and strategic thinking.

- **Competency portfolios**: Learners collect artifacts, annotations, and feedback related to their performance over time. These portfolios serve not only as summative records but also as instruments for self-assessment and goal setting.

Each of these assessment modes must be purposefully selected and aligned with the competencies targeted. A mismatch between task, context, and evaluation criteria can lead to false signals of progress or penalize learners with different learning styles or strategies.

Ensuring Trustworthiness and Scalability

To scale assessment practices across programs and institutions, reliability and validity must be consistently maintained. This involves the use of shared rubrics, cross-evaluator training, and calibration sessions to ensure inter-rater consistency. It also includes processes for validating that assessment tasks are appropriately challenging and representative of the competencies they aim to measure.

Digital technologies can assist in this process by offering structured data collection, instant feedback mechanisms, and reporting dashboards that enable real-time tracking of both individual and cohort-level development. However, systems must remain adaptable and allow educators to override automated judgments when necessary.

The ultimate aim of assessment in VR/XR/AI-based CBE is not certification alone but learning. Feedback derived from assessment should inform the next steps in the learner's journey, indicating which competencies need further development and how to pursue that development. This recursive function transforms assessment from a gatekeeping tool into a developmental instrument, reinforcing learner autonomy, resilience, and accountability.

In immersive and AI-enhanced settings, assessment is no longer a separate stage in the learning process. It is integrated into every interaction, every task, and every decision the learner makes. The challenge for educators and system designers is to ensure that these assessments remain transparent, equitable, and empowering.

1.4.6 Metrics suitable for XR/AI environments.

Measuring learning in environments shaped by extended reality (XR) and artificial intelligence (AI) requires rethinking how educational progress is defined and tracked. Traditional metrics, such as test scores, attendance, or course completion rates, often fail to capture the complexity of learner engagement and the dynamic nature of interactive, multimodal experiences. In XR/AI-enhanced learning, students do not merely consume content but participate in situations that simulate real-world conditions. As a result, assessment must move toward more sensitive and responsive indicators of both process and outcome.

Instead of focusing solely on whether a student arrives at the correct answer, evaluators must look at how the learner navigates the task, the reasoning involved, the adaptability demonstrated, and the socio-emotional responses triggered by the activity. These dimensions are central to the e-DIPLOMA project’s goal of integrating digital and socio-emotional competences into a competency-based education (CBE) model.

Rethinking What Metrics Should Capture

Metrics for XR/AI environments need to reflect several interwoven aspects of learning, many of which are difficult to measure using traditional tools. These include real-time decision-making, collaboration in immersive environments, persistence after failure, and the transfer of knowledge to novel contexts. Rigid test-based indicators are poorly suited for this purpose. Instead, data must be collected through meaningful learner interactions that happen in situ, during task performance or social exchanges within virtual settings.

Metrics should be designed not only to assess knowledge acquisition but also to capture how learners apply what they know. For example, a student navigating a multi-user VR environment might not only be judged on the outcome of a collaborative project, but also on how they contribute ideas, negotiate tasks, or respond to constructive disagreement. AI-based systems are particularly well-suited to monitor such behaviors unobtrusively, recording timestamps, language use, gesture frequency, or eye movement to create a multifaceted performance profile. Given D.2.1 results, track design-linked indicators (e.g., experiential phase progression, interactivity level, sensory channels used) alongside performance to explain variance in learning gains.

Key Categories of Metrics

Metrics in XR/AI settings can be grouped into several overlapping categories. While these are not exhaustive, they reflect dimensions that appear across the literature and practice of CBE in immersive and AI-supported contexts.

1. Performance Metrics

These indicators capture the learner's ability to complete tasks aligned with the intended learning outcomes. In XR environments, performance is observable through actions such as manipulating virtual objects, navigating simulated spaces, or responding appropriately to scenario prompts. AI can track time-on-task, solution accuracy, number of attempts, and other variables that give a picture of efficiency and mastery.

2. Process Metrics

These metrics focus on how learning unfolds, rather than just the final result. They are especially important in competency-based systems, where formative assessment plays a critical role. Examples include the sequence of decisions made in a simulation, the types of errors encountered and corrected, or the strategies employed to overcome challenges. AI can be used to identify patterns in learner behavior, such as reliance on trial-and-error, use of external resources, or responsiveness to feedback.

3. Affective and Engagement Metrics

XR/AI environments are particularly effective in eliciting emotional responses. Emotional and motivational engagement are key indicators of whether a student is likely to persist, collaborate, or transfer learning beyond the classroom. Metrics here include indicators like participation frequency, willingness to explore complex paths in a simulation, or interaction with peers and tutors. Eye-tracking, voice tone analysis, and self-reporting tools can help triangulate emotional engagement, though ethical safeguards must be applied.

4. Social Interaction Metrics

When learners interact with peers or AI agents in virtual settings, their collaborative behavior becomes part of the learning data. Metrics might include turn-taking in discussions, frequency of peer support, responsiveness to others' inputs, or conflict resolution skills. These indicators are relevant for evaluating socio-emotional competencies, especially in tasks designed to develop empathy, negotiation, or perspective-taking.

5. Adaptability and Transfer Metrics

An important function of XR/AI assessment is to evaluate how well students can apply competencies across new or evolving situations. A learner may be exposed to a modified version of a task they previously completed and asked to solve it under different constraints. The ability to generalize prior knowledge, apply flexible strategies, or draw on feedback from earlier experiences can be measured through performance variability and problem-solving novelty.

For metrics to be meaningful, they must correspond to clearly articulated competencies. The e-DIPLOMA project, for example, emphasizes both digital and socio-emotional competencies, such as problem-solving in digital contexts, responsible technology use, empathy in communication, and adaptability in group settings. Metrics need to reflect these priorities.

Rubrics and dashboards built into XR/AI systems can help visualize competence development over time, though caution is needed to avoid overly mechanical representations. A bar that turns green may signal mastery, but it tells little about the learner's journey or the conditions under which the skill was demonstrated. That is why many educators recommend combining quantitative indicators with qualitative evidence, such as recorded sessions, reflective journals, or peer observations.

Technical Considerations and Limitations

While XR and AI afford the possibility of detailed, continuous assessment, they also introduce challenges. Not all learning can or should be measured, and not all metrics carry equal interpretive weight. Furthermore, there is the risk of reducing learning to what can be easily tracked by a system, rather than what is meaningful in a pedagogical or ethical sense.

Another concern involves data overload. In immersive systems, every movement or action can be logged, but not all of it is relevant. Educators and designers must determine which data points truly inform learning and which create noise. There is also the risk of reinforcing existing biases if AI-driven assessments rely on limited or culturally biased training data.

Additionally, learners must understand what is being measured and why. Transparency in how metrics are defined, collected, and interpreted is crucial to maintaining trust and motivation. Metrics that remain hidden or poorly explained may encourage performative behaviors or disengagement. Where values concerns (autonomy, surveillance) are salient, disclose what interaction data feed metrics and allow opt-outs without penalty.

Toward a Multi-Layered Assessment Ecosystem

The most effective use of metrics in XR/AI environments comes from a multi-layered assessment ecosystem. Automated systems provide real-time data, while educators offer interpretive insight. Learners themselves should be involved in monitoring progress and reflecting on their performance. Such an approach aligns with the vision of CBE as a participatory, feedback-rich model of education.

Ultimately, the value of a metric is not in its sophistication but in its capacity to support learning. Whether simple or complex, a metric should inform action, reveal growth, and help learners navigate their educational paths with greater clarity and purpose.

To conclude, the integration of XR and AI technologies into competency-based education introduces both immense potential and a set of complexes, unresolved questions. As this chapter has illustrated, the move toward competency-based frameworks in immersive and intelligent environments demands a thorough rethinking of what it means to assess, support, and recognize learning. Competence is no longer confined to a student's ability to recall or replicate content. It is increasingly understood as the demonstrated capacity to act meaningfully in uncertain, often collaborative, and digitally mediated contexts.

This shift is not merely technical. It reshapes pedagogical assumptions, institutional practices, and even learners' relationships with knowledge. The rise of flexible learning pathways, real-time feedback systems, and AI-supported assessments seems to offer unprecedented responsiveness to individual learner needs. Yet, this apparent adaptability may conceal underlying tensions. For instance, when metrics are tied too closely to system-generated outputs, there is a risk that education becomes reactive rather than reflective, data-driven rather than learner-centered.

Competency-based models grounded in XR/AI contexts suggest a path forward where assessment is deeply embedded in the act of learning itself. Instead of interrupting learning to test it, educators may now observe how learners navigate complexity, demonstrate agency, and transfer understanding across modalities. However, this also places new demands on educators, who must develop fluency not just in pedagogy, but also in the interpretation of machine-generated data, in the design of responsive learning environments, and in the ethical implications of surveillance-based feedback.

It is not entirely clear, at this stage, how far current XR/AI-enabled systems are from fulfilling this vision. Early implementations may still rely on legacy assumptions about learning outcomes, or they may inadvertently amplify disparities through opaque algorithms or inaccessible interfaces. Furthermore, the vocabulary surrounding competencies—terms such as skill, qualification, proficiency, and outcome—remains contested, even among experts. This semantic ambiguity may appear trivial, yet it shapes how curricula are designed and how learner success is understood.

Despite these uncertainties, one thing becomes evident: educational institutions can no longer afford to separate learning design from learning evaluation. In XR/AI environments, these processes co-evolve. Metrics are not external to learning; they are built into it, whether by intention or default. Consequently, a strategic and cautious approach is required—one that recognizes the importance of granular data, but resists reducing complex cognitive and emotional processes to simplified indicators.

In the context of the e-DIPLOMA project, this evolving assessment landscape calls for flexible, robust, and ethically informed frameworks. These frameworks must accommodate diverse learning trajectories, recognize socio-emotional development alongside digital fluency, and prioritize learners' ability to act competently in unpredictable, real-world situations. At the same time, educators and designers must accept that not all learning is measurable, and not all outcomes can be anticipated.

To move forward, institutions may need to balance experimentation with structure, innovation with accountability, and automation with human judgment. Likely, the future of XR/AI-enhanced education will not hinge on a single model of assessment, but rather on an ecosystem of approaches that are adaptable, context-sensitive, and grounded in pedagogical intent. Competency-based education offers a compelling vision—but its success will depend not only on what is measured, but on how we choose to interpret and act upon what those measurements reveal.

1.5 Policy Recommendations Based on WP2 Findings

Objective:
Ensure a coherent, ethical, and sustainable integration of VR, XR and AI technologies in European education systems by strengthening pedagogical quality, institutional capacity, and digital inclusion.

Concrete actions:

At EU level:

- Strengthen the **European policy framework for immersive and AI-enhanced education** through targeted funding lines, interoperability standards, and guidance on ethical and inclusive digital transformation.
- Support the creation of **European shared-service infrastructures** and open repositories for XR/AI educational resources, governed by FAIR and accessibility principles.
- Encourage cross-national benchmarking and evidence exchange through coordinated actions under the **Digital Education Action Plan** and Horizon Europe.

At regional level:

- Develop **innovation ecosystems and digital learning hubs** connecting schools, universities, training centers, and local industry to share VR/XR/AI infrastructures and expertise.
- Facilitate **regional partnerships and funding calls** that support experimentation and scaling of inclusive immersive learning models, particularly in under-resourced areas.

At the local/institutional level:

- Implement **curriculum mapping and co-creation processes** that align VR/XR/AI tools with defined learning outcomes and student needs.
- Foster **continuous professional development** through peer mentoring, micro-credentials, and communities of practice.
- Conduct **ethical and accessibility impact reviews** for all VR/XR/AI initiatives, ensuring informed consent and opt-out options for learners.

Responsible actors:
European Commission (DG EAC, DG CONNECT), national governments and regional education authorities, quality assurance agencies, universities and training providers, EdTech developers, and European research networks.

Expected impact:

– Coherent and scalable integration of immersive and AI technologies in education.

– Greater pedagogical effectiveness and competence-based learning evaluation.

– Equitable access to infrastructures and resources across Europe.

– Strengthened trust and transparency through ethical, inclusive governance.

– Multi-level coordination and policy alignment supporting long-term sustainability.

Chapter 2: Pilot Results and Practical Evidence from VR/XR/AI Prototypes

2.1 Overview of Piloted Technologies and Scenarios

The piloting phase of the e-DIPLOMA project offered valuable insights into how immersive and intelligent technologies perform in real educational settings. Rather than relying solely on abstract evaluations, the piloting activities provided a grounded perspective on the strengths, limitations, and contextual needs associated with VR, XR and AI deployment in classrooms. This hands-on testing contributed not only to technological validation but also to pedagogical understanding of what works and what may still require refinement.

A variety of VR/XR tools and platforms were tested across different institutions and learning environments. Among the most frequently used solutions were ClassVR, CoSpaces Edu, Merge EDU, and 360° VR applications. These platforms were selected based on accessibility, prior experience of the institutions, and alignment with curriculum objectives. In some cases, the tools were already known to teachers, while in others, they were introduced, allowing for a more exploratory and open-ended use.

The range of subjects and age groups in the pilot sessions was deliberately diverse. Some pilots focused on secondary school learners, while others engaged primary education or vocational and training contexts. For instance, science lessons involving human anatomy and environmental education frequently use 3D models and virtual environments to increase learner engagement. History and geography classes integrated 360° experiences that placed students inside simulated historical events or distant ecosystems. These cases suggest that immersive content appears particularly well-suited to topics requiring spatial awareness, multi-sensory understanding, or contextual immersion.

In addition to subject matter, the environments in which the pilots occurred varied. Some institutions carried out the testing in fully equipped Smart Labs or VR/XR classrooms. Others operated in standard classrooms with mobile VR headsets, showing that immersive experiences can be introduced even in settings with limited infrastructure, although usability and immersion quality were understandably affected by the degree of available equipment. In several instances, Wi-Fi stability and hardware robustness became bottlenecks, particularly during group sessions.

Not all technologies were implemented uniformly. ClassVR, for example, was used both for guided explorations and independent learning, depending on the instructional goals. CoSpaces Edu was frequently leveraged in creative assignments, where students built their own virtual environments, a practice that appeared to support learner agency and creativity. In contrast, Merge EDU was primarily used in science-related disciplines, offering visualizations of physical objects in augmented reality, which may have enhanced conceptual clarity, especially in younger learners.

Teachers reported a wide range of experiences depending on their level of digital confidence and the support structures available. Where institutions had dedicated facilitators or technical staff, the adoption process appeared smoother. In cases where teachers were left to experiment independently, results varied. This points to the importance of contextual readiness—not only in terms of infrastructure, but also regarding institutional culture and professional development.

The pilots also attempted to examine the role of AI-assisted tools in the classroom. Although this aspect was less uniformly present across all participating sites, some institutions began experimenting with adaptive quiz generators, AI-based pronunciation coaches, and chatbots designed to scaffold learning tasks. The use of AI remained more exploratory than systematized, but it provided early indications of both interest and hesitation among educators.

Taken together, the pilot activities illustrate a pattern of cautious optimism. Technologies were not introduced as isolated novelties, but integrated within pedagogical goals. The level of depth and consistency varied, as expected in experimental phases, yet the results provide a strong foundation for refining future implementation strategies. Furthermore, the diversity of settings—urban and rural, well-resourced and constrained—adds important nuance to the conversation about what is possible, what is practical, and what is still aspirational in the integration of XR and AI across European educational systems.

2.2 Evidence from the Pilots (Results and Replicable Practices)

The piloting phase of the e-DIPLOMA project yielded a number of encouraging results that hint at the transformative potential of VR, XR, and AI in education. While the scale of the pilots was intentionally limited and contextual factors varied significantly, there are recurring patterns suggesting that these technologies, when used thoughtfully, can strengthen several dimensions of the learning experience. At the same time, some of the practices that emerged appear flexible enough to be adapted and replicated in other educational settings, provided that local conditions are adequately taken into account.

Across most piloting sites, teachers and facilitators noted a visible increase in learner engagement and motivation during XR-enhanced sessions. Learners appeared more focused, enthusiastic, and willing to participate when immersed in 3D environments or interactive simulations. In science-related modules, for instance, abstract concepts such as molecular structure or ecological systems became more tangible and easier to grasp when students could interact with visual and spatial representations rather than rely solely on textual or static diagrams.

Some students reported that VR/XR activities helped them "feel" the topic rather than just "study" it. Although this kind of feedback remains subjective, it may suggest that immersive learning has the potential to support deeper emotional and cognitive connections with content. This effect was especially noted in primary and lower-secondary settings, where attention span and sensory engagement are key factors in the learning process. However, even older learners seemed to benefit when VR/XR was aligned with clear learning objectives.

The pilots also helped identify teaching strategies that worked well alongside VR, XR and AI. One commonly reported approach was to use immersive experiences as preparatory or exploratory tools before formal instruction. For example, a VR visit to a historical site was introduced before a lecture on the same topic, which allowed students to anchor abstract timelines and concepts in a more memorable visual experience. Teachers observed that this strategy appeared to improve classroom discussion and information retention.

Another replicable practice involved student-created content, especially in platforms like CoSpaces Edu. In these cases, students were not only consumers of digital materials but also authors of their own learning environments. This model appeared to foster creativity, peer collaboration, and a sense of ownership over learning. Teachers who embraced this approach often noted an improvement in classroom dynamics and student confidence, although the time investment required for such activities remains a practical consideration.

AI-supported feedback tools, while less widely used across pilots, also showed promise in specific contexts. In language learning, pronunciation tools driven by speech recognition algorithms allowed students to receive instant correction and encouragement, which may have reduced performance anxiety for some. Similarly, AI-driven quizzes and adaptive learning paths gave teachers new ways to monitor progress without constant manual intervention. These tools, when integrated thoughtfully, seem to offer both efficiency and personalization, though several educators emphasized the need for clearer ethical guidelines and technical transparency.

Importantly, these outcomes were not confined to high-tech environments. Some schools used relatively simple setups—such as cardboard VR headsets and tablets—to test VR/XR applications. Even in these constrained conditions, the core benefits of immersion and interaction were still perceived, though often limited by connectivity issues or the number of available devices. This highlights that while infrastructure is a key enabler, pedagogical creativity and teacher readiness play an equally critical role.

Not all elements worked equally well everywhere. However, when VR, XR, and AI were embedded in coherent lesson plans, introduced with adequate preparation, and supported by aligned learning objectives, the results were largely positive. These findings suggest that the value of these technologies may not lie in their novelty alone, but in the way they are framed and delivered within the educational journey. With proper guidance and contextual adaptation, many of the strategies tested during the e-DIPLOMA pilots could be scaled up or transferred to similar settings, both within and beyond the consortium.

While the piloting phase of the e-DIPLOMA project offered promising glimpses into the potential of VR, XR and AI in education, it also surfaced several challenges that underline the importance of careful planning, flexibility, and ongoing evaluation. These challenges were not unexpected; in fact, many had been anticipated during earlier phases of the project. What proved most instructive, however, were how educators and project teams responded and adapted to these obstacles in real time.

Technical limitations emerged early and frequently. A number of institutions involved in the pilots faced issues related to hardware compatibility, outdated operating systems, and unreliable internet connections. Some VR/XR applications demanded processing power that older school devices simply could not provide. Even where the devices were functional, installations could be delayed by slow Wi-Fi or difficulties in accessing digital platforms due to school-level firewalls or device management policies. These problems often disrupted planned activities and, in some cases, required last-minute reconfiguration of sessions.

Usability was another concern. Although many of the VR/XR platforms tested were designed for educational use, they still demanded a level of digital fluency that not all learners—or teachers—possessed. Some students struggled with the interface logic of certain VR platforms, particularly when instructions were not offered in their native language or required fast-paced navigation. This occasionally led to frustration or disengagement, especially among younger students or those with learning difficulties. In response, educators often had to redesign sessions on the fly, simplify activities, or assign students to work in pairs to offer mutual support.

Cognitive overload was also frequently reported. Immersive technologies, by their very nature, offer high-density stimuli: vivid visuals, spatial interactions, and sometimes audio layers all compete for attention. While this intensity can enhance engagement, it may also lead to fatigue or distraction, particularly if exposure is prolonged or not well-paced. In several pilot scenarios, teachers observed signs of restlessness or tiredness after extended XR use, prompting discussions about time limits and the need for screen breaks.

To address these concerns, several adaptations were introduced. One commonly applied solution was to shorten the duration of VR/XR sessions and follow them with offline reflection or group discussions. These transitions helped consolidate learning and allowed students to step back from the immersive environment. Some educators used printed worksheets or verbal debriefings to prompt metacognitive reflection, helping learners connect the digital experience with the curriculum.

Diversity among learners also required pedagogical flexibility. In inclusive classrooms, educators noted that neurodivergent students sometimes needed more structured support to navigate VR/XR environments. Visual clutter, unexpected sounds, or non-linear navigation features were described as potentially disorienting. In response, teachers adjusted the content pacing, offered simplified interfaces, or selected VR/XR tools with customizable settings. Where such customizations were not available, traditional support strategies—such as previewing the session or assigning digital mentors among peers—proved helpful.

Another recurring theme was teacher confidence and workload. While many educators were open to experimenting with VR/XR/AI tools, some felt that the preparation time required to understand and integrate these technologies was unsustainable without additional institutional support. Limited technical support, lack of local expertise, and pressure to “make the technology work” within fixed lesson plans sometimes created stress. To mitigate this, peer-to-peer learning networks were encouraged in several pilot sites, allowing teachers to share quick fixes, lesson formats, and even co-teach VR/XR modules in teams. These informal systems of collaboration appear to have reduced the sense of isolation and lowered the barriers to experimentation.

Finally, the pilots underscored the importance of expectation management. Some participants had initially hoped that XR or AI would provide instant improvements in motivation or learning outcomes. When the results were more mixed, it became clear that success with these tools depended as much on pedagogical framing as on technical execution. The most successful sessions, according to feedback, were not the ones that used the flashiest tools, but rather those where digital activities were deeply aligned with learning goals and learners’ cognitive and emotional needs were taken seriously.

Taken together, these lessons suggest that the path to integrating VR, XR and AI in education is not linear or free of tension. However, the pilots show that thoughtful, learner-centered adaptations can reduce many of the risks and create conditions where digital innovation truly enhances learning. The work of adjustment, feedback, and redesign is not incidental—it is part of the learning curve that institutions must navigate when adopting emerging technologies.

Table 13. Challenges and Adaptations in VR/XR/AI Pilots for e-DIPLOMA Project

Challenge	Description / Examples	Adaptations / Responses	Key Insights
Technical Limitations	- Hardware incompatibility (older devices, weak processing power) - Outdated operating systems - Unreliable Wi-Fi - Firewalls or device management blocking access	- Reconfigured sessions last-minute - Adjusted lesson plans to available devices - Institutional awareness of infrastructure needs	Reliable infrastructure is a precondition; technical fragility disrupts pedagogy.
Usability Barriers	- Some VR/XR platforms required higher digital fluency than students/teachers had - Interfaces in non-native languages - Fast-paced navigation created difficulties	- Simplified activities - Redesign of sessions on the fly - Pair/group work for mutual support	Accessibility and intuitive design critical; peer support reduces exclusion.
Cognitive Overload	- Intense sensory input (visual, spatial, auditory) - Fatigue and distraction after extended sessions	- Shorter VR/XR sessions - Built-in breaks - Offline reflection (worksheets, discussions, debriefings)	Balance between immersion and reflection needed; pacing is essential.
Learner Diversity	- Neurodiverse students found VR/XR overwhelming (visual clutter, non-linear navigation, sudden sounds) - Different learning needs in inclusive classrooms	- Adjusted content pacing - Simplified interfaces - Customizable settings where available - Preview sessions, peer mentoring	Inclusive design and scaffolding reduce disorientation; adaptability is key.
Teacher Confidence & Workload	- Extra preparation time burdensome - Limited technical support - Stress of integrating tech into fixed lesson	- Peer-to-peer learning networks - Informal collaboration and co-teaching - Shared lesson	Teacher support networks mitigate stress; institutional backing is vital.

	plans	formats and fixes	
Expectation Management	- Over-optimism about instant learning gains - Mixed results when tools not aligned with pedagogy	- Realignment of focus toward pedagogy-first use - Emphasis on learning goals and emotional needs over flashy tools	Success depends on pedagogy, not just novelty; realistic expectations crucial.

2.3 Lessons from Teachers and Students

Understanding how VR, XR, and AI tools are experienced by the people who use them daily, teachers and students, is essential for shaping future strategies. The qualitative feedback gathered during the piloting phase of the e-DIPLOMA project offers valuable insight into both the promise and the pressure that accompany digital transformation in education.

From the perspective of teachers, reactions varied widely depending on the context, previous exposure to digital tools, and availability of support. Several educators expressed a strong sense of enthusiasm about the pedagogical opportunities offered by immersive and intelligent technologies. They noted how VR/XR scenarios made abstract concepts more concrete, how student engagement increased when using interactive platforms, and how AI-supported learning paths allowed for differentiated instruction. In language learning, for example, the chance to simulate real-world communication through VR environments was viewed as especially effective. That said, this enthusiasm was often tempered by pragmatic concerns.

A recurring theme in the teacher responses was the need for more targeted and timely training. As one community leader put it: “Some teachers are hesitant or untrained in using digital tools. Tech remains underused despite student interest. Teacher confidence and competence are key to integrating innovation.” Many reported feelings underprepared for the technical setup or unsure about how to integrate digital tools meaningfully into their curriculum. Rather than broad training on generic platforms, teachers emphasized the value of subject-specific workshops, continuous mentoring, and hands-on practice with the actual tools used in their classrooms. Some suggested that even short peer-led sessions or collaborative planning time would be preferable to one-off webinars or general training courses.

There were also reflections about the balance between novelty and sustainability. While educators appreciated trying something new, several expressed concern that VR/XR and AI could quickly become unsustainable add-ons unless supported by long-term institutional planning. For these tools to become part of regular teaching practice, they argued, school leadership must recognize the need for protected time, curriculum adaptation, and technical assistance. Without these systemic adjustments, the risk is that only the most confident or tech-savvy teachers will continue to use the technologies beyond the pilot phase.

From the student perspective, feedback was generally positive but nuanced. Many students reported that VR/XR tools made lessons feel more alive and memorable. They appreciated the opportunity to explore, manipulate, and interact with content in ways that traditional lessons often do not permit.

Some mentioned feeling more focused, while others said the immersive nature of VR/XR helped them better understand complex topics—especially in science, geography, or vocational subjects. At the same time, not all students had an equally smooth experience.

Some learners, particularly younger students or those unfamiliar with the technology, described initial disorientation or confusion when first entering virtual environments. Others commented on physical discomfort, such as eyestrain or fatigue, especially when headsets were used for extended periods. These concerns were echoed in several teacher observations and have led to discussions about age-appropriate duration guidelines and the need for integrated breaks.

Students also pointed out gaps in digital content quality. While some applications were well-developed and aligned with the curriculum, others felt more like games with unclear objectives. When tasks lacked relevance or structure, students reported lower motivation and sometimes even boredom. This feedback suggests that effective digital learning is not only a matter of providing access to tools, but also ensuring thoughtful instructional design and strong pedagogical scaffolding.

Another interesting strand in the feedback involved student agency. Learners who were given choices—such as selecting the order of activities or customizing their virtual environments—tended to report a stronger sense of ownership over their learning. This sense of autonomy appears to enhance motivation and may support longer-term engagement, especially when linked to reflective or metacognitive tasks.

Finally, both teachers and students stressed the importance of integration, not substitution. They were generally supportive of blending VR/XR/AI tools with existing classroom routines rather than replacing traditional methods altogether. This cautious optimism suggests that the future of digital education may lie not in radical reinvention, but in careful, context-sensitive layering of new tools into existing pedagogical cultures.

In sum, the feedback collected during the e-DIPLOMA pilots points to a clear conclusion: while VR/XR and AI have considerable potential to enrich education, their success depends on the lived experiences of those implementing and using them. Listening closely to teachers' practical concerns and students' experiential feedback is not an optional extra—it is a cornerstone for building sustainable, equitable, and meaningful digital learning environments.

2.4 From Evidence to Policy Directions

Throughout the e-DIPLOMA project, an important goal has been to not only identify theoretical frameworks and international best practices, but also to test their actual feasibility in diverse educational settings. The piloting phase offered a unique opportunity to observe how models that appear promising on paper play out in practice. The gap between intention and implementation may at times seem modest, yet it often reveals critical insights that could shape more realistic and adaptable digital education strategies.

There is, on the surface, a strong degree of alignment between the conceptual frameworks presented in earlier work packages and the practices tested during the pilots. For instance, the idea of integrating VR, XR and AI into student-centered, experiential learning aligns well with what was observed in classroom trials involving platforms such as CoSpaces and ClassVR. Teachers reported increased engagement when students were given opportunities to explore immersive content, while students themselves responded positively to environments where they could interact with learning materials rather than passively receive information.

However, the divergences are equally noteworthy. One recurring discrepancy involves the idealized timelines and resource assumptions embedded in many international models. Theoretical recommendations often assume that infrastructure, bandwidth, hardware, and training are already in place or easily attainable. In contrast, pilot feedback repeatedly pointed to technical friction, limited digital infrastructure, and the steep learning curves faced by educators. These obstacles suggest that policy guidance must not only be pedagogically sound but also logistically grounded and sensitive to material constraints.

Another area of tension concerns the role of teacher autonomy and institutional flexibility. While best practices tend to promote co-creation, adaptive learning, and personalized feedback, the actual implementation of these concepts requires a significant degree of pedagogical freedom and administrative support. In rigid or highly centralized educational systems, these conditions may not yet exist. During the pilots, some educators expressed frustration at the lack of space to adapt curricula or introduce new tools in meaningful ways, even when the theoretical model encouraged it. This reveals that contextual factors—from national policy frameworks to school-level culture—play a substantial role in determining the success or failure of digital transformation efforts.

Moreover, while international examples highlighted in *D.2.1 Best Practices Report* provided aspirational benchmarks, transferability proved to be uneven. What works in a well-resourced school in Northern Europe may not translate smoothly to a rural or underfunded setting elsewhere. Factors such as language, curriculum standards, teacher training pathways, and student digital readiness all influence whether a “proven” model can be scaled or replicated. For this reason, several pilot institutions opted to localise tools or adapt lesson structures, sometimes deviating from the original model in order to meet their learners’ needs. These adaptations, though sometimes modest, played a crucial role in making technology adoption more effective.

Interestingly, there were also moments where practice informed theory in unanticipated ways. For example, student responses around cognitive load and motion fatigue led to deeper reflections on the ergonomics of immersive learning environments—something that had been underemphasised in the original best practice models. Similarly, the peer mentoring observed among teachers organically evolved into a sustainable professional development strategy, even though it was not initially framed as a formal training component.

In sum, the comparative insights drawn from the e-DIPLOMA pilots suggest that while theory provides essential direction, it must be consistently revisited and refined in light of on-the-ground experience. Implementation success appears to rely less on universal templates and more on adaptability, responsiveness, and a willingness to make space for local innovation. It is this interplay between conceptual clarity and practical flexibility that will ultimately determine whether digital tools in education become truly embedded and transformative, or remain peripheral and episodic.

The e-DIPLOMA project, through its documentation of both external best practices and internal pilot experiences, has built a complex and evolving picture of what makes educational technology integration effective. Drawing from the findings across multiple contexts, it becomes possible to identify certain signals of success, as well as tensions and turning points that can inform future efforts.

One of the central insights emerging from both the theoretical review and classroom trials is the importance of **flexibility** when identifying promising practices. No single model or tool appears to work equally well in every context. However, practices that tend to succeed often share specific characteristics: they are adaptable to existing infrastructure, pedagogically aligned with curriculum goals, and well-received by teachers and learners alike. In the pilots, for instance, tools such as CoSpaces proved more effective when teachers had the autonomy to tailor content, while ClassVR worked best in settings where technical support was consistently available. This suggests that identifying promising practices requires more than technical performance metrics; it involves observing usability, uptake, and contextual compatibility over time.

Adapting these practices to new national, regional, or institutional settings involves more than translation or scaling. It requires **contextual interpretation**. A tool or methodology that fits well within a digitally mature school may require substantial modification to function in under-resourced environments. In several pilot sites, success depended not on strict replication of models but on deliberate and thoughtful **localization**. This included adjusting content for linguistic diversity, synchronizing digital tools with national curriculum standards, and adapting training formats to reflect the professional routines of teachers. It appears unlikely that a one-size-fits-all solution will emerge; instead, a patchwork of locally nuanced applications seems more sustainable.

Another critical takeaway concerns the **role of co-creation**. While much of the initial design thinking in VR, XR and AI for education has been top-down, the pilots demonstrated how involving teachers, learners, and even parents early in the process can dramatically improve outcomes. When educators were invited to shape the pacing, content, or format of immersive activities, their sense of ownership grew—and so did student engagement. This implies that sustainable implementation is less about introducing tools and more about building ecosystems of collaboration. Co-creation may not only support better alignment with classroom realities, but also function as a long-term investment in digital literacy and institutional capacity.

Feedback loops, both formal and informal, emerged as a silent yet powerful ingredient in scaling good practices. In several cases, small iterative adjustments based on classroom experiences helped teams avoid friction or disengagement. Where systems allowed for real-time adaptation—whether through peer mentoring, ongoing dialogue with developers, or responsive leadership—the integration of technology became smoother and more meaningful. Conversely, rigid implementation without teacher input tended to result in low uptake or superficial use.

Finally, successful implementation may require a shift in how educational change is understood. Rather than focusing solely on the introduction of technology, future strategies might benefit from framing VR, XR and AI integration as part of **institutional transformation**. This broader perspective could open up space for systemic support: long-term professional development, participatory governance structures, and inclusive policy alignment.

Taken together, these takeaways do not point to a narrow list of actions. Instead, they invite a more holistic mindset—one that treats educational innovation not as a fixed solution to be delivered, but as a dynamic and relational process that must be cultivated, challenged, and co-shaped in context.

Table 16. Key Takeaways for Future Implementation of VR/XR/AI in Education

Theme	Insight	Implications for Practice
Flexibility in Promising Practices	Effective VR/XR/AI practices were not defined by technology alone but by their adaptability to diverse institutional and pedagogical settings. Tools like CoSpaces performed better when educators could tailor content to learner needs.	Focus on selecting technologies that offer room for pedagogical adaptation, not just technical performance. Evaluate tools over time in real-world conditions, not through isolated pilots.
Contextual Adaptation	Success depended on local conditions such as infrastructure, language, curriculum, and teacher preparation. Tools had to be adjusted to align with national standards and available resources.	Avoid assuming scalability without modification. Translate and localize content; adapt training to teacher routines; align tools with curricular expectations in each context.
Co-Creation as Enabler	Involving educators, students, and sometimes parents early in design led to better alignment with classroom realities. Ownership and engagement increased when participants shaped the pace, content, and structure.	Build co-creation mechanisms into early planning phases. Encourage institutional cultures that support shared design and reflection, even if it slows initial rollout.
Feedback Loops and Iteration	Informal feedback and incremental changes often prevented disengagement. Teachers who could adjust tools in response to student input reported better uptake and learning outcomes.	Create opportunities for regular feedback through mentoring, developer dialogue, and internal review. Plan for iteration, not linear deployment.
Reframing Implementation	Technology adoption worked best when embedded in broader institutional change—teacher training, curriculum redesign, and leadership buy-in.	Treat VR/XR/AI as part of a transformation process, not just a product to implement. Align with institutional strategy, governance, and capacity-building plans.
Holistic Mindset	Innovation is not a fixed intervention but a dynamic and relational process shaped by	Build systems that evolve. Prioritize reflection, collaboration, and inclusive

	policy, culture, and human actors.	values over speed or novelty. Use VR/XR/AI to deepen—not replace—pedagogical purpose.

2.5 Policy Recommendations Based on WP5 Pilot Results

Objective:
Leverage pilot evidence to build scalable, equitable, and pedagogically sound implementation models for immersive and AI-enhanced education.

Concrete actions:

At the EU level:

- Support large-scale evaluation pilots under Erasmus+ and Horizon Europe to test scalability and cost-efficiency of XR/AI-based teaching.
- Establish European guidelines on workload, accessibility, and ethical use in immersive classrooms.

At the national level:

- Include pilot-tested models in national digital education strategies and teacher training frameworks.
- Fund structured peer-mentoring and support networks replicating successful pilot collaborations.

At the regional level:

- Create innovation clusters or demo hubs linking schools, universities, and local EdTech providers.
- Provide regional grants to upgrade infrastructure following pilot-tested minimum standards.

At the local/institutional level:

- Adopt co-creation and feedback loops observed in pilots as formal practices.
- Incorporate reflection sessions and accessibility checks into regular teaching design.

Responsible actors:
European Commission, national ministries of education, regional authorities, universities, schools, and EdTech partners.

Expected impact:

– Scalable and context-sensitive models for immersive learning.

– Reduced inequality in digital readiness.

– Sustainable teacher training ecosystems.

– Ethical, inclusive, and learner-centered innovation.

Chapter 3: Stakeholder-Driven Policy Proposals for Multi-Level Action on VR/XR/AI in Education

The WP6 phase of the e-DIPLOMA project aimed to capture the perspectives of key educational stakeholders, including students, teachers, school leaders, policymakers, researchers, and technology providers, through structured **brainstorming sessions** and participatory workshops. It will cover the types of stakeholders, the national context, the level of influence, as well as main challenges surfaced during sessions, and recommendations emerging as a result.

3.1 Participatory Process and Stakeholder Mapping

One of the defining features of the e-DIPLOMA project is its firm commitment to participatory methodologies. Central to this approach were a series of brainstorming sessions held across the seven partner countries—Spain, Italy, Estonia, Hungary, the Netherlands, Cyprus and Bulgaria—each designed to gather grounded, context-specific insights from diverse stakeholder groups. These sessions aimed to bridge the gap between technological innovation and the lived realities of those engaged in education daily. They served not only to generate recommendations, but also to validate assumptions, uncover local needs, and surface tensions that may not be visible in top-down policy processes. Recognizing the limitations of top-down policymaking in the context of rapidly evolving educational technologies, the project adopted a participatory framework that sought to capture insights from a diverse cross-section of actors, situated across different levels of institutional influence. This approach ensured that proposed policy recommendations reflected both strategic priorities and the lived realities of those working and learning within education systems.

The sessions were designed with the following core **objectives**:

- To gather grounded, context-specific proposals from educational stakeholders.
- To facilitate collaborative ideation and peer refinement of proposals.
- To support the selection and prioritization of policy options based on stakeholder input.
- To ensure transparency and traceability of idea development through structured documentation.

The stakeholder composition of each session was carefully curated to reflect the levels of influence relevant to educational innovation: low and medium. These groups are formed not in a hierarchical manner, but rather according to the level of their regular institutional involvement and practical political effect. This stratification ensured that both grassroots practitioners and policy-level decision-makers had a chance to be represented. The variety in stakeholder types across countries highlighted the richness and complexity of educational ecosystems, as well as differing levels of engagement and readiness for disruptive technologies like VR/XR and AI. Low influence group includes learners, representatives of families, community leaders and technology and educational researchers. Generally, this group of participants do not have formal access to the decision-making process. Medium influence groups included representatives of NGOs, educators, experts, course providers, and post-doc researchers.

6-5-3 Brainstorming Model

For moderate and low-influence groups, each national partner organized 6-5-3 brainstorming sessions This is a structured method designed to foster distributed participation and iterative idea refinement. The key parameters of this process were as follows:

- 6 participants were selected per stakeholder group.
- Each participant proposed 5 initial policy ideas.
- Over a cycle of 3 rotations, participants reviewed and built upon each other's ideas.
- After the final round, participants collectively reviewed and shortlisted the most viable proposals.
- Selection criteria included feasibility, potential impact, and alignment with project goals.

This method allowed for asynchronous collaboration accommodating participants' schedules and encouraging thoughtful, layered input. A shared online repository (e.g., Google Drive) was used to centralize all working materials, with separate folders for each country and each influence level. Optionally, interactive platforms such as Miro or MURAL were available to support real-time co-creation.

This methodology was crucial for various reasons, as it:

- Enables asynchronous participation.

Participants from different time zones and institutional schedules can contribute on their own time, making it practical for a geographically distributed consortium.

- Encourages equal input from all participants.

The structured rotation format limits dominance by more powerful voices and ensures contributions from a wide range of stakeholders, including those with lower institutional influence.

- Generates a large volume of policy ideas efficiently.

With 6 people generating and refining 5 ideas each, the method can quickly produce a wide variety of valuable and creative proposals for evaluation.

- Produces structured, ready-to-analyze outputs.

Because ideas are written, refined, and tracked systematically, the results can easily be compiled and used in WP6 policy drafting without requiring extensive restructuring.

- Supports co-creation and participatory values of the project.

The method embodies e-DIPLOMA's commitment to inclusive, bottom-up policy development by integrating a wide diversity of voices in a transparent and methodical way.

Low and Medium Influence Groups: Students, Families, Teachers, Developers

Across the participating countries, teachers featured most prominently, and their insight were invaluable. They managed to highlight both the objective barriers emerging in the learning process and pedagogical concerns related to the integration of disruptive technologies. For instance, they voiced frustrations about time and training, but their comments often went beyond technical gaps. Several worried aloud about what it might mean for the teacher's role if digital systems begin to dominate classroom routines, or how far one can push technological mediation before learning feels depersonalized.

Students, particularly those consulted in Estonia, Hungary, Cyprus and Italy, had a rather different perspective. They were quick to point out the practicalities: how awkward some platforms felt to navigate, how much they valued face-to-face interaction, and how motivation flagged when digital learning became isolating. Equity as an issue came up repeatedly. One Hungarian group noted that while city schools had reliable high-speed internet, rural areas still struggled with outdated devices and poor connections, and that is among the very common concerns that we will look deeper into in the following chapters.

Families were less numerous in the sessions, but their contributions were striking. In Spain, and Bulgaria, parents described the strain of taking on greater responsibility for their children's learning during periods of online instruction. Some admitted they did not feel digitally literate enough to support complex platforms. Others worried about the long-term developmental effects of extended screen time, a theme that sometimes revealed intergenerational tension between parents and adolescents.

Developers, especially those working with XR applications in the Netherlands and Estonia, brought in a more technical lens. They spoke about current limits of the software, such as lag, hardware costs, and interoperability, and were often eager to discuss co-design opportunities with educators. A few stressed that without clearer ethical guidelines and some form of long-term strategy, new tools risked becoming isolated pilots that never scaled.

Cross-Country Patterns and Variations

While the structure of the brainstorming sessions was consistent across countries, the distribution of stakeholder types varied in emphasis. For example:

- Italy and Spain featured strong representation from teachers and regional education officials, reflecting their decentralized educational governance structures.
- Estonia and the Netherlands, with more digitally mature systems, placed heavier emphasis on technology experts and institutional strategists.
- Hungary and Bulgaria included more contributions from families and local community representatives, highlighting concerns about access, infrastructure gaps, and resistance to change in certain regions.

Despite the differences across countries and groups, one concern kept surfacing: how to match lofty visions of digital transformation with the reality of day-to-day practice. Participants at every level talked about the difficulty of coordinating roles and responsibilities, and many admitted they needed more guidance and ongoing support just to keep pace with constant technological change.

To make the workshops run more smoothly, several practical supports were introduced. A policy template gave participants a common format for writing down proposals, though a few noted that the rigid structure sometimes limited how they framed their ideas. Short orientation videos were used at the start of sessions; these were generally well received, although some participants preferred live explanations. Digital whiteboards were offered for mapping and clustering ideas, but not every group chose to use them—comfort with online tools varied widely. Finally, groups were invited back for review sessions, where they compared and voted on proposals. The use of scoring rubrics helped structure the discussion, yet in some cases the numbers overshadowed the more nuanced arguments that people wanted to make.

3.2 Cross-Country Findings and Thematic Areas

The e-DIPLOMA project grew out of a fairly simple question: how should education respond when technologies like VR, XR and AI start to reshape not only how knowledge is delivered, but what counts as learning in the first place? The project framed this question in terms of equity and innovation, but also with an eye to something more pragmatic—how to make new tools usable for teachers and students without eroding the relational depth that education depends on. That balance has not been easy to strike. As earlier chapters made clear, the introduction of immersive and intelligent systems brings technical headaches, new ethical risks, and genuine uncertainty about how assessment or pedagogy should evolve. Chapter 6 takes up these tensions and moves toward possible policy directions.

This is not meant to be a master plan. What follows is closer to a synthesis of themes that cropped up repeatedly in discussions among consortium partners and stakeholders. Some of the concerns were fairly local—differences in infrastructure between rural and urban schools, for instance—while others reflected wider questions about how innovation gets financed and governed across Europe.

The material for this chapter comes from brainstorming sessions held with a deliberately mixed group: students, teachers, families, policy officials, developers, and school leaders. The process itself was somewhat structured (we adapted the 6-5-3 method for online settings, with moderators guiding the flow), but the outputs were messy in the best sense. Proposals were coded, sorted, and sometimes quantified, though the numbers are less important than the kinds of urgency people attached to them.

What stands out from this exercise is less a unified roadmap than a cluster of concerns pointing in different directions. Some are plainly technical—connectivity, access to devices, platform reliability. Others cut deeper, raising issues of pedagogy and teacher preparation, or the need to rethink assessment frameworks that do not fit immersive environments. Still others turned to the emotional weight of digital learning, the strain on teachers, or the risk of alienating learners. Taken together, the proposals suggest that what stakeholders want most is flexibility: room to experiment without losing institutional stability, and policies that can bend to context rather than impose a uniform template.

Rather than isolating VR, XR and AI as separate technological silos, the proposals suggest that successful integration depends on policy frameworks that are both systemic and modular. Educational systems may require guidance not only on how to deploy these technologies, but also on how to govern them, how to train human actors, and how to measure their impact without reducing learning to what is merely quantifiable. There is also some ambivalence expressed—implicit in the proposals—about the extent to which VR/XR/AI should shape, rather than merely support, educational practice. This may suggest that technology adoption remains embedded in broader pedagogical cultures that resist standardization.

This chapter aims to organize these reflections and proposals into a set of strategic areas. The intention is not to impose priorities but to offer a scaffolding that can inform local policy development, institutional planning, and cross-border collaboration. Each strategic area is presented with a short analytical rationale and a summary of relevant proposals. Where appropriate, intersections between areas are acknowledged, particularly where recommendations cut across infrastructure, curriculum, assessment, or wellbeing.

In aligning these recommendations with the e-DIPLOMA values, the chapter preserves the project's foundational emphasis on co-creation, inclusivity, and digital sovereignty. The resulting policy scaffolding is thus designed to be adaptable across diverse educational ecosystems while remaining rooted in participatory insight.

What follows is a detailed exploration of the ten most salient strategic areas identified during the co-creation process, followed by a cross-cutting synthesis and a forward-looking roadmap. These are not endpoints, but evolving tools intended to inform a dynamic and sustainable transformation of education in the age of VR, XR, and AI.

Key Strategic Policy Areas

The aggregation and analysis of brainstorming session data revealed several recurring themes that appear to define the strategic horizon for VR, XR, and AI integration in education. These policy areas were not selected arbitrarily; rather, they emerged organically from the distributed insights of diverse stakeholder groups across the e-DIPLOMA consortium. While the number of proposals offers a useful indicator of collective prioritization, the relative importance of each theme is not solely a matter of frequency. Some areas, though less discussed, carry considerable strategic weight due to their long-term implications or foundational nature. The structure of this section, therefore, follows a dual logic: it is anchored in the quantitative distribution of suggestions, while remaining attentive to the systemic value and cross-cutting relevance of each domain. From immersive learning environments to teacher training, from digital equity to wellbeing, the identified policy areas reflect not just current needs but evolving aspirations for a digitally responsive and inclusive educational ecosystem. As such, this chapter should be read as both a snapshot of stakeholder priorities and a forward-looking map for institutional and policy-level interventions within the e-DIPLOMA framework.

VR and Immersive Learning

With a total of **262 suggestions**, VR/XR and immersive learning emerged as the most prominently discussed theme across all brainstorming sessions. This volume of input suggests not only widespread interest but also a collective intuition that these technologies are poised to shape the next phase of digital education. While the enthusiasm is notable, the breadth of contributions also reflects a growing concern: if not carefully implemented, the promise of XR may remain more aspirational than transformative.

Participants consistently highlighted the pressing need for investment in hardware and infrastructure. Many educational institutions, particularly in under-resourced contexts, appear to be constrained by the high costs and technical demands associated with immersive tools. VR headsets, spatial audio systems, and motion-tracking hardware are still inaccessible for many classrooms. Several contributors pointed out that without equitable access to these tools, any pedagogical ambition involving XR may remain limited to pilot projects or well-funded institutions.

Beyond hardware, another cluster of suggestions concentrated on the creation of smart labs and dedicated immersive learning environments. These spaces are imagined not only as sites for experiencing virtual content but as flexible, interdisciplinary hubs where students and educators can co-create simulations, engage in virtual prototyping, or conduct scenario-based exercises. The proposals seem to imply that without such dedicated environments, the integration of XR may end up as a superficial overlay on traditional classroom settings, rather than enabling genuinely new forms of learning.

Equally important, though perhaps less often discussed in the public discourse around VR, is the pedagogical dimension. A considerable number of suggestions stressed the need for instructional frameworks and teacher guidance tailored to immersive environments. Designing meaningful learning experiences in XR requires not just technical proficiency but a shift in how educators approach content, interaction, and assessment. This may involve, for instance, rethinking the sequence of lessons, adapting pacing to non-linear exploration, or preparing learners to navigate simulated environments with both cognitive and emotional awareness. Without targeted support, educators may find themselves overwhelmed by the novelty of the medium or unsure how to translate familiar pedagogical goals into immersive formats.

Although some participants expressed cautious optimism, the general tone of the contributions suggests a shared concern: enthusiasm alone will not guarantee meaningful integration. Infrastructure must be met with pedagogy, and access must be coupled with strategy. At the policy level, this implies that recommendations related to VR and immersive learning should not focus exclusively on procurement or one-time investments. Instead, they must attend to the full ecosystem of adoption, including training, curriculum alignment, iterative evaluation, and long-term institutional support.

In sum, the density and consistency of contributions around this theme signal that immersive learning is no longer a fringe concern. It appears to be moving toward the center of strategic planning in digital education, albeit with significant challenges still to be addressed. For e-DIPLOMA, this area is likely to remain a cornerstone of policy innovation, demanding both imagination and practical coordination across institutional and national contexts.

AI in Education

The integration of Artificial Intelligence in education emerged as one of the most frequently discussed and strategically significant themes across the brainstorming sessions (**185 suggestions**), with 16 distinct proposals addressing this domain. These contributions span a wide range of perspectives, yet coalesce around a few key dimensions that warrant closer examination.

A dominant theme involves the potential of AI to facilitate personalised and adaptive learning pathways. Several proposals advocate for AI-driven systems capable of responding to students' individual needs, learning styles, and progress patterns. This orientation appears to reflect a growing confidence in the technological maturity of adaptive learning platforms and their promise to address longstanding challenges of differentiation within classrooms. At the same time, however, there remains a sense of intellectual hesitation about scalability and inclusivity. While proponents envision sophisticated, responsive systems, concerns surface regarding uneven digital access, algorithmic bias, and the potential reinforcement of educational inequalities.

Another cluster of proposals highlights AI's capacity to support educators through intelligent tutoring systems, workload reduction tools, and predictive analytics for identifying at-risk students. The intention is not to replace teachers, but to augment their capabilities. The emphasis here shifts from learner-centered AI applications to institutional and pedagogical infrastructure, suggesting a more systemic vision of digital transformation. Some proposals recommend the establishment of national or institutional AI strategies to ensure that implementation is not fragmented but coordinated, accountable, and aligned with broader educational objectives.

Ethical considerations run throughout the discussions. Many proposals articulate a strong need for regulatory and governance frameworks capable of safeguarding privacy, ensuring transparency, and embedding human oversight into automated decision-making processes. There is a notable call for the development of clear ethical guidelines and legal instruments to regulate the use of AI tools in both public and private educational settings. This emphasis on normative dimensions may indicate a broader shift in how educational innovation is conceptualized—not solely as a technological or pedagogical matter, but also as an ethical and political one.

Despite the divergence of proposals in terms of scale and scope, the overall direction points toward the need for strategic foresight. Policymakers appear to recognize that AI's educational potential cannot be fully harnessed without significant institutional redesign, investment in teacher training, and the cultivation of public trust. The proposals gathered here suggest a growing awareness that AI in education is not merely a tool, but a force likely to reshape the roles, relationships, and expectations that structure teaching and learning. Whether this transformation will promote equity and inclusion remains contingent on the frameworks within which AI is introduced and governed.

Teacher Training and Capacity Building

Among all policy themes discussed during the national brainstorming sessions, teacher training and capacity building emerged as one of the most pressing and recurring concerns, reflected in **313 proposals**. This number alone suggests that, across different countries and stakeholder profiles, educators are widely seen as pivotal actors in the successful integration of VR, XR and AI technologies into formal learning environments. Yet, at the same time, they are also frequently perceived as underprepared, overwhelmed, or unequipped to take on that role effectively.

Proposals from participants conveyed a strong sense of urgency, even frustration, regarding the current state of professional development for educators. Many educators reportedly feel isolated in the face of rapid technological changes, with little institutional support or space to develop the necessary digital, pedagogical, and ethical competencies. In some cases, the recommendations framed teacher training not as a supplementary aspect of policy implementation but as its primary precondition.

A recurring suggestion involved the design and rollout of mandatory upskilling programs specifically tailored to VR, XR and AI integration. These would ideally not only focus on technical know-how, but also include critical reflections on the pedagogical and social implications of using such technologies in the classroom. While national-level frameworks for such training were frequently proposed, several stakeholders also called for flexibility, allowing schools and educators to adapt content based on context and available infrastructure.

What seems to resonate across countries is the need for sustainable, peer-driven models of capacity building. Top-down seminars or one-off workshops were often described as inadequate. Instead, participants proposed teacher mentoring networks, collaborative communities of practice, and long-term partnerships with research institutions and technology developers. The idea here is not only to increase digital competence, but to foster a culture of co-creation, experimentation, and mutual support among educators.

Another thread running through the recommendations concerns the interdisciplinary nature of the required skillset. Teachers are expected not only to understand how to operate XR tools or interact with AI platforms, but to do so in a way that aligns with ethical principles, developmental psychology, inclusive pedagogy, and sometimes even national legal frameworks on data privacy. Proposals suggested that training programs should therefore avoid being siloed into “technology-only” modules. Instead, they should be embedded in broader curricula that encourage pedagogical imagination and critical thinking around technology.

Not all voices in the sessions expressed unqualified enthusiasm. A few stakeholders questioned the feasibility of asking already overburdened teachers to take on additional training responsibilities without corresponding adjustments to their workload or compensation. Others expressed skepticism about the assumption that all educators will—or should—become tech-savvy at the same level, advocating instead for differentiated roles within teaching teams, where some teachers may act as digital leads or facilitators.

What seems likely, based on the volume and tone of the input, is that if teacher training continues to be treated as an afterthought rather than a cornerstone of VR, XR and AI adoption, educational systems risk widening existing gaps rather than bridging them. The call, then, is for training ecosystems that are adequately resourced, context-sensitive, and grounded in the actual experiences of educators themselves.

In short, teacher training and capacity building may not guarantee the success of technology integration, but without them, failure appears almost inevitable.

Curriculum and Pedagogical Innovation

Curriculum and pedagogical innovation emerged as a strategic policy area, reflected in at least **115 proposals** submitted across the brainstorming sessions. While not always the most frequently cited topic, it appears to function as a foundational concern that cuts across other thematic areas, particularly those related to immersive technologies and teacher development. Participants consistently pointed to the need to rethink and restructure educational content and formats to better align with the affordances and challenges of VR, XR, and AI-enhanced environments.

Rather than simply inserting digital tools into existing curricula, many stakeholders argued for the creation of flexible, modular, and context-sensitive learning pathways. These should, in their view, accommodate diverse student needs, including those shaped by regional infrastructure limitations, linguistic diversity, or differing levels of digital literacy. The idea of "curriculum elasticity" surfaced in multiple sessions, often tied to concerns that rigid national standards may inhibit experimentation and localized adaptation.

Another recurring theme was the integration of immersive and interactive experiences into formal learning outcomes. Educators and students alike questioned whether current pedagogical frameworks are equipped to capture the experiential and embodied nature of VR/XR learning. For example, proposals suggested including narrative-driven simulations, real-time collaborative problem-solving tasks, and cross-disciplinary projects as formal components of curriculum design. Some also called for regulatory flexibility to allow teachers to pilot and iterate VR/XR-supported pedagogies without bureaucratic delays.

The discussion was not without ambivalence. Several contributors raised concerns that, unless grounded in sound educational theory and accompanied by adequate teacher training, attempts to "innovate" curricula could result in fragmented learning or increased inequality. There was a noticeable caution against novelty for its own sake. Instead, proposals stressed the importance of aligning pedagogical innovation with actual learning needs and long-term educational goals.

A few sessions pointed to the potential for curriculum innovation to support non-traditional learners, including adult students, neurodivergent learners, or those with interrupted education. XR and AI were seen as enablers of differentiated instruction, but only if curricular structures were redesigned to support autonomy, pacing, and diverse assessment types.

Taken together, the proposals reflect a shared belief that curriculum innovation must not be seen as an add-on to technological integration, but rather as its prerequisite. Without a corresponding shift in pedagogical thinking and curriculum development, VR, XR and AI tools are unlikely to generate meaningful change in educational outcomes. The policy challenge, then, is to create environments—both regulatory and institutional—where educators have the freedom, support, and capacity to adapt their teaching to a rapidly evolving technological landscape.

Digital Literacy and Media Competence

Although not the most frequently cited topic in the brainstorming sessions, at least **51 proposals** addressing digital literacy and media competence reveal a deeper concern running beneath the surface of VR/XR/AI integration. Several participants pointed to an emerging gap between the growing complexity of digital tools used in education and the actual skills of learners, teachers, and even families. This gap may not be as immediately visible as hardware shortages or regulatory barriers, but it appears to exert a slow and steady drag on the transformative potential of technology-enhanced learning environments.

The term *digital literacy* was not always used uniformly. Some participants focused on foundational skills such as navigating digital platforms, understanding data privacy settings, or using educational apps effectively. Others leaned toward broader and arguably more demanding forms of competence, such as the ability to distinguish credible sources of information, interpret algorithmic bias, or engage critically with immersive media environments. In some cases, "media competence" was used interchangeably with "digital citizenship," reflecting a wider cultural dimension of technology use that includes ethical, social, and psychological aspects.

One recurrent suggestion was the development of national digital literacy frameworks that would define learning outcomes across age groups and education levels. These frameworks, it was argued, should be aligned with European competence reference models but also adapted to local contexts. There was also a call to include digital literacy not only as a transversal element in existing curricula but as a clearly articulated subject with its own instructional time, assessment criteria, and teacher training pathways.

Participants stressed that critical thinking should not be treated as an abstract goal but embedded into hands-on activities, such as evaluating VR content, participating in simulated online debates, or analyzing AI-generated texts. Some proposals even suggested co-creating digital content with students as a way of fostering more active engagement with the media landscape they inhabit. The idea here was not just to prepare students to use digital tools, but to empower them to shape and question the digital world itself.

The data from the brainstorming sessions suggest that digital literacy is seen less as a discrete competency and more as a foundational layer for all other aspects of digital education. Without it, even the best XR hardware or the most personalized AI tool risks being misunderstood, misused, or simply underutilized. Embedding media competence at the core of education appears to be one of the few strategic moves that can ensure long-term, socially responsible innovation.

Wellbeing and Screen Time

Among the themes that emerged in the brainstorming sessions, concerns around well-being and screen time surfaced with notable urgency. A total of at least **71 proposals** directly or indirectly addressed the emotional, cognitive, and physical effects of prolonged interaction with digital technologies, particularly in the context of immersive VR, XR, and AI-enhanced educational environments. While enthusiasm for technological integration was evident across stakeholder groups, this topic appears to introduce a cautionary dimension into an otherwise future-focused policy dialogue.

Participants raised questions about how increased screen exposure might affect student attention spans, emotional regulation, and mental health, especially in younger learners. These concerns, while not always grounded in comprehensive longitudinal data, reflect a broader unease that is mirrored in both popular discourse and emerging psychological studies. In this sense, the proposals may signal a broader shift in educational values, where digital innovation is no longer viewed in isolation but is increasingly evaluated through its implications for human well-being.

The suggestions varied in their scope and specificity. Some advocated for integrating digital wellbeing frameworks into school policies, suggesting that educational institutions should explicitly define what constitutes a "healthy" digital learning environment. Others went further, calling for institutional roles—such as digital wellbeing coordinators—tasked with monitoring, supporting, and designing balanced engagement strategies. A recurring recommendation was the promotion of media literacy that includes reflection on one's digital habits, emotional responses, and cognitive fatigue.

Interestingly, proposals often expressed support for a more balanced use of immersive technologies—advocating not for restriction, but for moderation and thoughtful design. For instance, several proposals recommended alternating XR-based learning activities with outdoor, social, or analogue experiences to maintain a sense of physical and emotional equilibrium. Such strategies, though logistically complex, point to a pedagogical shift toward hybrid, human-centered digital practices.

There was also a noticeable emphasis on teacher awareness and capacity. Proposals suggested that professional development programs should include modules on identifying early signs of digital fatigue or emotional distress in students. Some proposals went as far as to suggest developing new tools—perhaps even AI-driven—that could help monitor levels of cognitive overload during XR sessions.

These recommendations align with broader values central to the e-DIPLOMA project: inclusivity, sustainability, and a commitment to participatory design. The insistence on safeguarding learner wellbeing illustrates how stakeholders are not only interested in what technology can do, but also in what it might unintentionally displace. By integrating these concerns into strategic policy discussions, the project can avoid the pitfall of tech-driven reform that overlooks the human dimension of learning.

Overall, the frequency and quality of suggestions in this area suggest that well-being should not be treated as a peripheral concern. Rather, it appears to be emerging as a foundational principle that can guide how VR, XR, and AI are deployed across diverse learning contexts

Assessment and Evaluation

A recurring theme across the brainstorming contributions (at least **62 proposals**) involves a deep concern with how current assessment practices may fall short in capturing the full range of learning experiences made possible by VR, XR, and AI. Many contributors questioned whether traditional summative exams or rigid grading systems could adequately reflect the competencies learners are expected to develop through immersive or adaptive platforms. One of the participants shared her experience. Instead, they called for assessment mechanisms that are more flexible, process-oriented, and aligned with learner-centered models.

Several proposals advocate for authentic assessment tools capable of measuring applied knowledge, problem-solving, and socio-emotional development in real-world or simulated tasks. This appears to signal a broader shift toward performance-based evaluation, where learning is not just about retention of content but about the ability to demonstrate understanding in practice. In this regard, immersive environments are seen not only as instructional spaces but also as testing grounds for learners' skills in dynamic, often collaborative contexts.

There is also noticeable interest in leveraging AI for formative evaluation, particularly through adaptive technologies that can monitor learners' progress in real time. Such systems, it is suggested, could provide ongoing feedback to students and educators, allowing for more responsive teaching strategies and timely support. However, this enthusiasm is often tempered by concerns over data privacy, transparency of algorithms, and the potential dehumanization of educational judgment if AI systems are relied on too heavily.

Another thread running through these recommendations involves competency-based evaluation frameworks. These were discussed not merely as buzzwords but as structural reforms that could help align learning outcomes with broader educational goals. Yet several participants expressed uncertainty over how to operationalize such frameworks in day-to-day school practice, pointing to the need for clearer guidelines, capacity building, and integration with national qualification systems.

Some proposals also emphasized the need for interoperability and standardization, warning that a fragmented ecosystem of assessment tools could hinder comparability of outcomes across institutions. Others called for shared repositories of validated VR/XR/AI assessment models, co-developed by educators, technologists, and pedagogical researchers.

Overall, the contributions under this policy area suggest that while there is widespread support for rethinking assessment in the context of VR, XR, and AI, a coordinated strategy is required to guide implementation. This would likely involve not only technological investments but also teacher training, ethical oversight, and institutional reform. The diversity and volume of proposals in this area reflect both the complexity of the task and the urgency with which stakeholders believe it must be addressed.

Accessibility and Inclusion

Among the many aspirations expressed through the e-DIPLOMA brainstorming sessions, perhaps none strike a more urgent tone than the desire to ensure that the digital transition in education does not reinforce existing inequalities (at least **144 proposals** explicitly or implicitly address the problem of accessibility and inclusion). While VR, XR, and AI technologies offer new forms of engagement and potentially greater flexibility, they also carry the risk of creating or widening gaps for those already at the margins—students with disabilities, those in rural areas, and families lacking economic or digital capital. This tension surfaced repeatedly in the stakeholder proposals, often implicitly, but in several cases, quite directly.

The data collected reveal a growing concern over whether immersive technologies are truly built for all learners. A number of contributors pointed out that many existing VR/XR systems are not designed with universal accessibility in mind. The assumption that all students can use VR headsets or navigate AI-driven platforms smoothly does not hold when physical, cognitive, or socio-economic differences are factored in. Some participants flagged the lack of support for screen readers, difficulties in adapting interfaces for neurodiverse learners, or the absence of tactile feedback for students with visual impairments.

In response, the recommendations advocate for a strategic shift toward inclusive design from the outset, rather than attempting to retrofit accessibility features after the fact. This includes applying universal design principles in the procurement and development of VR/XR/AI tools, ensuring that developers work in collaboration with accessibility experts, and involving users with disabilities early in the design process. It was suggested that public agencies and ministries of education could play a coordinating role by developing national guidelines or certification frameworks to evaluate the accessibility of educational technologies.

Some proposals go further, arguing for targeted public investment in assistive technologies and adaptive hardware. There was interest, for example, in supporting schools with subsidies to acquire alternative input devices or voice-command interfaces that could help students with motor limitations participate in immersive learning experiences. Several educators also emphasized the importance of training—not only for technical staff, but for teachers, who may need guidance on how to identify and address hidden accessibility barriers.

Beyond hardware, equity concerns were raised about access to high-speed internet, digital devices, and stable home learning environments. This was particularly salient in feedback from rural regions, where VR, XR, and AI adoption risks being not just difficult, but practically unfeasible under the current infrastructure. Suggestions ranged from public-private partnerships to expand broadband coverage to the development of offline-compatible or low-data XR applications. The overarching aim is to avoid what some participants described as a "two-tiered system" of digital learning, where only the most resourced schools and families benefit from technological advancements.

Another layer to this conversation addressed cultural and linguistic inclusion. Several proposals underlined the need for VR, XR, and AI content to be available in multiple languages and to reflect diverse cultural perspectives. The emphasis here was not only on translation, but on representation—ensuring that students see themselves and their communities reflected in immersive environments.

Although fewer in number compared to more technical policy areas, the proposals on accessibility and inclusion carry disproportionate weight. They serve as a reminder that innovation cannot be divorced from justice, and that progress in education must be measured not just by technological sophistication, but by how widely and equitably it is felt.

By taking these insights seriously, the e-DIPLOMA project reinforces its core values—equity, diversity, and inclusion—ensuring that its vision for future-ready education does not leave anyone behind.

Ethics and Privacy

Among the most consistently recurring concerns across the brainstorming sessions, ethics and privacy emerged not as isolated policy domains but as cross-cutting principles influencing nearly every aspect of VR/XR/AI integration in education. These topics surfaced both implicitly, through expressions of unease about data use and surveillance, and explicitly, with participants calling for institutional safeguards and regulatory clarity. A total of at least **17 proposals** in the dataset directly or indirectly addressed issues related to the ethical governance of educational technologies and the handling of sensitive learner data.

Participants, particularly those from policy-making and academic backgrounds, voiced concerns about the growing opacity in how algorithms shape learning paths, assess students, or personalize content delivery. While AI-powered tools promise to improve individualization and efficiency, they also appear to operate in a largely unregulated space. Several stakeholders questioned whether current frameworks are equipped to handle the volume and granularity of data being collected on students' behaviors, emotions, and learning styles.

This concern was especially pronounced in contexts where VR/XR environments collect biometric and motion-tracking data. Teachers and student representatives alike flagged the need for clearer communication about what data is collected, how it is stored, and who has access to it. Proposals suggested that educational institutions should move toward developing their own internal ethics guidelines that align with broader data protection regulations but also go further in addressing pedagogical implications. Some also proposed mandatory audits of third-party educational tools to ensure transparency in algorithmic decision-making processes.

Another strand of suggestions focused on embedding ethical reflection in teacher training programs. There was a strong sense that educators are often placed in the position of mediating between technological tools and students, without sufficient preparation to assess the ethical dimensions of these tools. For example, one proposal recommended that teacher training include modules on algorithmic bias and consent literacy, especially in relation to AI tutors or predictive learning systems.

At the policy level, several contributors called for national strategies to set clearer boundaries for ethical AI use in education. These would include not just compliance with data privacy laws, but also the establishment of oversight bodies to monitor implementation practices in schools and universities. There was also interest in co-developing ethical standards in partnership with students, families, and community stakeholders, suggesting a move toward more participatory forms of governance.

While consensus on the exact shape of these frameworks remains elusive, the discussions point to an evolving awareness that ethics and privacy cannot be treated as afterthoughts. They must be embedded in the design and deployment of VR, XR, and AI technologies from the outset. If not, there is a risk that the same tools meant to personalize and enhance learning may inadvertently erode autonomy, reinforce bias, or undermine trust in digital education systems.

In short, this policy area is less about developing entirely new technologies and more about fostering a culture of responsibility, transparency, and shared accountability. The recommendations gathered suggest that ethics in education technology is not a standalone issue. Rather, it is the thread that connects all others—from curriculum design to infrastructure investment—and must be treated accordingly in both national and institutional strategies.

Infrastructure and Connectivity

A recurring concern voiced throughout the brainstorming sessions revolved around the foundational role of infrastructure and connectivity in enabling meaningful digital transformation in education (at least **122 proposals**). While the promises of VR, XR and AI in learning environments are compelling, their realization appears to be largely dependent on the availability of reliable technical infrastructure. For many stakeholders, particularly those in under-resourced schools or rural areas, the conversation about innovation begins and ends with whether the basic conditions are in place: a stable internet connection, functional devices, and sufficient bandwidth.

A total of 96 proposals directly addressed issues related to infrastructure, suggesting that this policy area remains one of the most urgent yet unevenly addressed. Contributors from multiple countries pointed out that the lack of robust digital infrastructure continues to act as a bottleneck, blocking the adoption of even low-threshold digital tools, let alone immersive or AI-powered technologies. The frustration was palpable in several recommendations, especially those that described classrooms where students must share outdated devices or schools that rely on patchy mobile hotspots for connectivity.

Investment in broadband infrastructure emerged as a common recommendation, although there were nuanced perspectives on how such investment should be prioritized. Some participants argued for immediate centralized action to ensure universal high-speed internet coverage in schools, while others suggested a tiered approach that starts with the most underserved regions. In parallel, the need for modern hardware—including VR-compatible devices, projectors, and audio-visual systems—was also frequently raised, not as a luxury but as a prerequisite for participation in contemporary digital education.

Several proposals took a longer view, calling for the integration of VR/XR/AI technologies into hybrid and remote learning environments. The vision here is not simply about bringing devices into classrooms, but about creating fluid, adaptable ecosystems that support learning across time and space. This includes infrastructure to enable virtual labs, remote simulations, and collaborative platforms that operate reliably outside the traditional school timetable.

There was also a degree of caution, particularly from educators and administrators who highlighted the risks of a widening digital divide. Without clear guidelines and equitable funding models, infrastructure upgrades might reinforce existing inequalities rather than mitigate them. A few proposals warned against rolling out VR/XR/AI tools in a piecemeal manner, pointing to past cases where expensive technologies were installed without long-term planning for maintenance, updates, or pedagogical integration.

Finally, a smaller subset of recommendations called for public-private partnerships to support infrastructure development, especially in areas where government budgets are limited. These proposals were pragmatic in tone, recognizing the role that EdTech companies can play, but also demanding clear accountability and alignment with public interest goals.

In sum, while infrastructure and connectivity might be seen as the background conditions for innovation, the weight of proposals in this area suggests they are very much foreground concerns. Until these structural issues are addressed, the full potential of immersive and AI-enhanced education is likely to remain out of reach for a significant number of schools and learners.

3.3 Cross-Cutting Recommendations

The proposals gathered throughout the e-DIPLOMA project, and especially those emerging from the brainstorming sessions, suggest a strong desire to reframe how digital innovation in education is approached. Rather than asking only what technologies to adopt, participants focused on how these tools should be introduced, adapted, and supported in ways that respect human needs and educational values. There appears to be growing awareness that adoption alone is not a guarantee of improvement, and that overlooking underlying conditions such as usability, ethics, accessibility, and sustainability can undermine even well-designed initiatives.

This chapter brings together such concerns. It does not aim to replicate the specific policy areas outlined earlier but instead offers a wider perspective on what might be called the “enabling environment” for VR, XR and AI in education. Human-centered design, participatory development, long-term equity, and trust in digital systems all surfaced repeatedly in the data, not just as background conditions but as active priorities voiced by those who will be using, managing, or learning with these technologies.

The data used here has been drawn primarily from the metadata collected during brainstorm sessions with stakeholders, which contains a rich and diverse set of proposals from a broad mix of stakeholders. These inputs were collected across partner countries using a structured method that allowed ideas to circulate, evolve, and be re-evaluated collaboratively. In addition, reflections from documents focusing on system usability, co-design, and ethical guidance have helped to refine and contextualize the patterns that emerged.

The purpose of this chapter is partly analytical, but mainly practical. If broader structural questions are ignored, the more specific recommendations outlined earlier risk remaining sound in principle but weak when integrated on the ground. There is a risk that a tool that seems effective in a small pilot may collapse once it is scaled up and placed under institutional pressures. For instance, a VR/XR simulation can look impressive in a lab, yet leave students in a real education setting disoriented after twenty minutes of use. Or AI platforms may deliver feedback at speed, but they also invite suspicion if learners or teachers cannot see how decisions are being made in a transparent way.

For these reasons, the chapter shifts the focus away from isolated tools and toward the ecosystem in which they can be implemented. Policymakers, school leaders, and program designers need to consider not only technical functions but also the organizational and human conditions that shape whether new systems are taken up or whether it is ignored or even resisted. The aim here is not to produce a manual of solutions but to raise considerations that connect local experiments with wider institutional and social commitments.

What follows is not intended as a definitive set of answers. It should be read instead as a working collection of ideas, shaped by practice and informed through dialogue, and still very much provisional. Certain points may prove meaningful in some contexts while remaining less relevant in others. Such unevenness is to be expected, and perhaps even unavoidable, when reflecting on the future of education in times of rapid change.

Human-Centered Design and User Experience

Across multiple stakeholder groups, the issue of how VR, XR and AI technologies feel to those who use them, physically, cognitively, and emotionally, emerged as a recurring theme. While discussions about infrastructure, curriculum, or digital skills tend to dominate the broader debate around EdTech adoption, it is the small frictions in day-to-day use that often determine whether a solution gains traction or ends up sidelined. Human-centered design, therefore, is not an aesthetic consideration but a functional necessity.

Several proposals, particularly from students, family representatives, and teachers, pointed to a consistent concern: many current VR/XR solutions are not designed with the school environment, or its users, in mind. For example, one submission noted that VR headsets are “extremely heavy and difficult for younger students to wear for more than a few minutes.” This issue limits **VR's applicability in young learning settings**. The contribution proposed to invest into “the development and production of VR headsets made for students. These gadgets should be light, flexible, and ergonomically designed to fit children's tiny frames.” These reflections underscore a critical, if sometimes overlooked, barrier to implementation: physical discomfort and ergonomic mismatch between tools and users.

The question of **cognitive overload** also surfaced in the proposals. Some students reported difficulty focusing when immersive experiences were “too stimulating” or when switching between VR/XR environments and traditional tasks, as “VR immersion can affect student well-being without proper limits.”. Student suggested various means to cope with dense and overstimulating environment in class, such as providing music designed for studying, so the class is not too silent during the independent work. Teachers likewise expressed concern about the lack of standardized usability protocols or pedagogical guidance for VR/XR tools. These comments suggest that usability is not merely about ease of navigation but also about balancing sensory engagement with attention and cognitive processing.

Proposals also emphasized the importance of **participatory design** processes. A number of contributions advocated for co-creation practices, calling on educational institutions and EdTech developers to involve students and teachers in every step of the design and testing process. Rather than imposing tools from the top down, co-creation was described as a mechanism for grounding new technologies in actual classroom needs, improving usability, and increasing buy-in. One submission proposed creating a national network of “multifunctional Smart Learning Labs” where XR content can be tested by learners and educators before it is implemented at scale. The proposal included forming a framework for Smart Learning Laboratories that “ensures that each lab has VR technology, block programming kits, and adjustable seating. It is important to consider safety, ventilation, and child ergonomics.”

Another recurring recommendation is related to **iterative testing and responsive feedback loops**. Tools should not be considered ‘finished’ once deployed. Several contributions suggested the integration of continuous feedback mechanisms, where learners and educators can report bugs, propose interface improvements, or suggest additional features in real-time. A proposal coming from a technology researcher, for instance, stated that “institutions should ensure that the feedback gathered is systematically analyzed and translated into actionable improvements in curricula and pedagogy. Suggest specific channels or tools (e.g., digital dashboards, annual surveys, workplace integration assignments) that could support the feedback loops without high recurring costs or administrative burden.” These proposals reflect a broader shift toward adaptive ecosystems that can evolve based on actual usage rather than fixed design assumptions.

Beyond the classroom, usability was also tied to **access and inclusivity**. For instance, students with sensory or physical disabilities frequently encounter additional challenges when engaging with VR/XR tools. In general, suggestions from all levels of participants included adjustable straps, voice navigation options, and larger interface elements for motor-impaired users.

Finally, **psychological safety** was another implicit dimension of user experience. Concerns were raised about disorientation, digital fatigue, and potential feelings of isolation within fully immersive environments. While these effects may vary across individuals, they highlight the importance of allowing learners to opt in or out of VR/XR activities and offering blended modalities as alternatives. Flexible learning spaces—both physical and digital—appear to be more than a convenience; they are essential for ensuring sustained engagement and learner well-being. Some families even suggested implementing regular evaluations of the emotional, motivational, and pedagogical impact of immersive technologies on students. These evaluations should be participatory (including teachers, students, and families), accessible in clear language, and serve to adjust the use of these tools according to evidence."

Taken together, the proposals offer a clear message: VR/XR/AI integration must begin not with technology, but with users. Tools should adapt to learners and educators, not the other way around, because human-centered design is not an optional feature, but it is rather the condition for responsible and effective digital transformation in education. Whether in headset design, content interaction, or classroom workflow, putting comfort, usability, and adaptability first is likely to make or break long-term adoption.

Table 3. Human-Centered Design and User Experience in VR/XR/AI Education

	Stakeholder Concerns	**Proposed Solutions / Recommendations**
Physical Comfort & Ergonomics	VR tools not designed for children; physical discomfort limits use	Develop lightweight, flexible, ergonomically designed tools; design classroom furniture and labs with child ergonomics, safety, and ventilation in mind
Cognitive Load & Attention	Overstimulation; difficulty switching between VR/XR and traditional tasks; well-being concerns	Provide calming elements (e.g., background music); establish usability protocols; balance sensory engagement with attention demands
Participatory Design & Co-Creation	Tools often imposed top-down; mismatch with classroom needs	Involve students/teachers in design and testing; create national networks of "Smart Learning Labs" for iterative experimentation
Iterative Testing & Feedback Loops	Tools treated as "finished" products; weak user feedback mechanisms	Integrate continuous feedback channels (dashboards, surveys, assignments); ensure data is systematically analyzed and translated into improvements
Accessibility & Inclusivity	Learners with disabilities face extra barriers	Add adjustable straps, voice navigation, larger interface elements, inclusive design features
Psychological Safety & Well-being	Risk of disorientation, fatigue, isolation in immersive environments	Allow learners to opt in/out; provide blended learning alternatives; conduct participatory evaluations of emotional, motivational, and pedagogical impact

Equity, Inclusion, and Gender-Sensitive Design

Discussions across the brainstorming sessions repeatedly returned to questions of access, representation, and the risk of exacerbating existing inequalities through technological integration. While VR, XR and AI tools are often presented as universal enhancers of learning, participants emphasized that such benefits may only materialize for some learners unless intentional strategies are adopted to address disparities from the outset. This concern was not marginal or isolated, as it appeared across proposals from student representatives, teachers, researchers, and EdTech professionals, indicating a growing shared awareness.

One recurring theme was the **unequal distribution of technological infrastructure** across schools and regions. Participants highlighted that rural or economically disadvantaged areas continue to experience limited access to reliable internet, modern devices, or dedicated digital spaces. "Remote and rural schools across Europe face persistent connectivity gaps that hinder digital learning," as it has been mentioned at one of the brainstorming sessions. The unevenness of technological infrastructure means that immersive and AI-powered education may be out of reach for many, reinforcing rather than closing educational gaps. Policy proposals suggested mechanisms such as targeted public investment, regional subsidies, or shared learning labs that could be jointly used by networks of schools. Participants of brainstorm sessions suggested various challenges to promote digital education in rural and remote areas, including providing the "seed funding for pilot hubs" in schools, youth clubs, and local sports organizations in order to motivate younger students to participate in sports through tech-enhanced formats. While such approaches may not eliminate structural inequalities, they are likely to ease the immediate barriers to entry.

Several submissions brought attention to the importance of **adapting VR/XR/AI tools for neurodivergent students** and those with physical or cognitive disabilities. Recommendations ranged from ensuring text-to-speech compatibility and customizable sensory inputs in VR environments to the creation of teacher training modules that incorporate inclusive design principles. In some proposals, immersive technologies were even positioned as a potential enabler for students who traditionally face challenges in standard classroom settings. Few platforms provide real-time captioning, voice control, or adaptive interfaces, which creates additional barriers. It has been highlighted during workshops that " many educational platforms fail to meet Web Content Accessibility Guidelines (WCAG), making them difficult or impossible to use for students with visual, auditory, cognitive, or motor impairments. Teacher training on inclusive digital pedagogy is inconsistent or absent in many countries. Multilingual learners and neurodivergent students often lack appropriately designed content and tools." Indeed, according to UNESCO's 2020 report, many students with disabilities were left behind during the COVID-19 pandemic because digital content was not made accessible for their needs (UNESCO GEM, 2020). One participant raised the issue of headset design that "excludes children with glasses or hearing aids," suggesting a lack of foresight in hardware development. Others proposed guidelines to ensure universal design principles are embedded from the outset. There were also very specific examples and targeted suggestions to solve overlooked issues. For instance, voice synthesis helps compensate for the slow and inaccurate reading typical of dyslexia. Therefore, platforms that use reading as a learning method should have integrated voice synthesis, and all materials must be readable by voice synthesis (no scanned PDFs). This is especially important in foreign language platforms where audio helps distinguish similar words, such as those differing by one or two letters. However, this potential hinges on early involvement of these learners in the design process and close collaboration with specialists in accessibility.

In terms of **gender-sensitive design**, contributors called for greater scrutiny of how content, avatars, and interaction dynamics in VR/XR/AI systems may unintentionally replicate harmful stereotypes or exclude non-dominant identities. Quote from one of the sessions: “Current EU regulatory frameworks lack a specialized mechanism focused on continuous bias monitoring in education AI tools, limiting timely detection and corrective action. Without oversight, biased AI risks undermining equal learning opportunities and trust in digital education innovations.” Some participants proposed involving gender studies experts in the prototyping phase or applying ethical review protocols to ensure inclusive representation. There was also concern that female educators and learners remain underrepresented in pilot projects or training programs involving advanced digital tools. These gaps are unlikely to close without active intervention. A few participants suggested mandatory diversity criteria for publicly funded EdTech initiatives as a potential corrective measure.

Another insight emerged around **cultural inclusivity**. Multiple entries noted that VR/XR content is often developed from a narrow cultural perspective, risking alienation or lack of relevance for students from diverse backgrounds. Among the key aspects of cultural bias, according to several participants of the brainstorming sessions, was a linguistic one. As it has been brought up, “many families feel excluded because digital literacy support is not available in their language or adapted to their cultural context.” One proposal argued for the development of open-source, modular VR/XR materials that could be culturally localized by teachers or communities themselves: “Content must be accessible in all EU languages and tailored to different literacy levels and cultural backgrounds”. While not without logistical hurdles, this approach could encourage a more participatory and bottom-up dynamic in immersive content creation. It should also be noted that together with concerns, participants expressed significant optimism in particularly in the capacity of digital education to solve to promote cultural inclusion and overcome culture-based stereotypes: “Broadening one's cultural horizons increases awareness of the world and helps individuals find their place in society. We must educate and raise awareness among new generations about the importance of active community participation and cultural exchange. A key challenge is ensuring these environments are truly inclusive and encouraging, especially for more introverted students.”

Underlying many of these recommendations is a widely held understanding that equity must be treated as a foundational principle, not a secondary consideration, in the implementation of XR and AI technologies in education. It must be designed in, tested early, and monitored continuously. Participants called for regular equity audits, participatory feedback loops, and the inclusion of underrepresented voices not just as beneficiaries, but as co-designers. There was also an implicit critique of overly top-down strategies that fail to capture the lived realities of diverse classrooms.

If the e-DIPLOMA project aims to foster meaningful transformation, then these voices point to a clear imperative: the digital transition must be inclusive by design, not merely by intention. The challenge lies not only in addressing access but in recognizing how identity, ability, and background shape every learner’s experience with technology. It is in this intersection that future policy must work—with humility, creativity, and a commitment to structural change.

Table 4. Equity, Inclusion, and Gender-Sensitive Design in VR/XR/AI Education

	Stakeholder Concerns	**Proposed Solutions / Recommendations**
Access & Infrastructure	Rural and disadvantaged areas lack reliable internet, devices, or digital spaces	Targeted public investment; regional subsidies; shared learning labs across school networks
Disability & Neurodiversity	Many VR/XR/AI platforms fail WCAG standards; limited accessibility features (e.g., captions, voice control); lack of inclusive teacher training; hardware excludes learners with glasses/hearing aids	Ensure universal design from the start; integrate text-to-speech, customizable sensory inputs, real-time captioning; provide teacher training in inclusive pedagogy; involve accessibility specialists and neurodiverse learners in design
Assistive Technologies	Learners with dyslexia or other reading difficulties struggle with standard text-based content	Incorporate voice synthesis in platforms; ensure all materials are voice-readable (no scanned PDFs); emphasize audio support in language learning
Gender-Sensitive Design	Risk of reinforcing stereotypes through avatars/content; underrepresentation of women in pilots and training	Include gender studies experts in design reviews; apply ethical protocols to VR/XR/AI content; mandate diversity criteria in publicly funded projects
Cultural Inclusivity	VR/XR content often reflects narrow cultural perspectives, alienating diverse learners	Develop open-source, modular VR/XR content; allow teachers and communities to adapt materials for local contexts

<u>Ethical Governance and Responsible Innovation</u>

As emerging technologies such as VR, XR, and AI continue to reshape the educational landscape, questions of ethical governance and responsible innovation have moved from the margins to the center of policy discourse. The e-DIPLOMA project, through the structured brainstorming sessions conducted across multiple European contexts, reveals that these concerns are not merely abstract or theoretical. On the contrary, they are an integral part of the daily experiences of educators, learners, families, and institutional actors attempting to navigate a rapidly evolving reality of digitally driven education.

Across the more than 150 proposals flagged with references to ethics, transparency, privacy, or data governance, participants repeatedly called attention to the structural vacuum surrounding these domains. “Parents worry about how their child’s data is used. AI may have hidden biases that affect grading or opportunities. Schools lack clear rules or understanding of these risks” - these are examples of contributors' concerns. However, while there may be isolated national initiatives or institutional codes of conduct, the overall picture appears fragmented. It seems that many stakeholders, especially those directly engaging with learners, feel insufficiently equipped or inadequately guided when it comes to handling sensitive student data, managing AI-assisted assessments, or addressing algorithmic bias.

One recurring theme involved the urgent need for institutional frameworks that clarify the **rules of engagement** with VR, XR and AI tools, particularly those involving learner profiling, real-time biometric feedback, and automated decision-making. Rather than assuming that technology providers will self-regulate, many proposals suggested that public education systems and ministries need to take the lead in defining ethical boundaries. These may include, for instance, mandatory impact assessments before new tools are introduced into classrooms, or the creation of ethics review boards within ministries or school districts. As one proposal stated, " the EU should embed ethics and digital citizenship education into school curricula, introducing mandatory ethics and digital citizenship module in primary and secondary education across EU member states. This will equip students with critical thinking, empathy, and resilience in online spaces, addressing rising concerns around misinformation, cyberbullying, and digital rights. Without ethical guidance, students risk becoming passive or harmful digital participants."

Another significant concern expressed by stakeholders was the **opacity of AI models** being deployed in educational contexts. Many participants highlighted that AI is often treated as a "black box"—a powerful but inscrutable decision-making entity whose outputs are rarely questioned. Several policy suggestions emphasized the importance of transparency, both in technical and educational terms. This might involve requiring companies to disclose their model's logic in accessible language or embedding critical AI literacy into teacher training curricula so that educators can better understand and interrogate algorithmic decisions that affect their students.

Privacy was not only discussed in legalistic terms but also through the lens of everyday classroom practice: "No standard framework for digital rights in education exists at the EU level. Many schools and platforms collect data without fully informing users. Teachers may face harassment or censorship online without clear protections. Students often don't know their rights regarding data, privacy, or consent". Stakeholders questioned, for example, how facial tracking in immersive environments might impact learners' emotional well-being or how long behavioral data collected through AI tutors should be stored. These inquiries led to a broader call for consent-based models of participation, where learners and their guardians are fully informed about what data is collected, how it is used, and what rights they have to request its deletion or correction.

Some proposals also reflected a more cautious, forward-looking stance. They urged that policy frameworks should not only address current tools but also anticipate the unintended consequences of technologies not yet fully mainstreamed. The use of predictive analytics in determining learner pathways or automating performance evaluation, for instance, may seem efficient at first glance. Yet participants noted that such systems could reinforce existing inequalities or fail to accommodate students with atypical learning trajectories.

In several countries, the discussion extended to procurement and vendor accountability. There was concern that outsourcing key educational functions to third-party platforms, especially when done without rigorous oversight, might create risks not only for data security but also for pedagogical autonomy. In response, some stakeholders recommended that public authorities develop certification processes for VR/XR/AI vendors, incorporating criteria related to transparency, accessibility, and ethical use of data.

Finally, the idea of "responsible innovation" emerged as an alternative paradigm. Instead of evaluating technologies solely based on efficiency or engagement metrics, this perspective urges consideration of their broader societal impacts. What values are encoded into educational algorithms? Whose assumptions about learning are embedded in immersive environments? How are notions of success, failure, or intelligence being reshaped by these tools? While clear answers may still be elusive, the participants in the e-DIPLOMA process seem to agree that these questions deserve a central place in the design and governance of the digital education ecosystem.

This chapter thus argues for a shift in how educational institutions and policy bodies engage with technological change—not as passive recipients of innovation, but as active stewards of ethical, inclusive, and transparent systems. The groundwork laid by the project's participatory methodology provides not only a repository of specific proposals but a broader cultural signal: the future of education must be governed not only by what is technologically possible, but also by what is socially just.

Table 5. Ethical Governance and Responsible Innovation in VR/XR/AI Education

	Stakeholder Concerns	**Proposed Solutions / Recommendations**
Lack of Institutional Frameworks	Fragmented national/institutional codes; educators feel ill-equipped to handle sensitive data, AI assessments, or bias	Develop clear institutional frameworks; establish ethics review boards; require mandatory impact assessments before classroom adoption
Opacity of AI Models	AI treated as a "black box"; decisions difficult to interpret	Require companies to disclose models' logic in accessible terms; embed AI literacy into teacher training so educators can interrogate outputs
Privacy & Data Governance	Concerns about facial tracking, emotional wellbeing, data storage duration, and consent	Adopt consent-based data models; ensure transparency on collection, use, deletion, and correction of learner data
Anticipating Future Risks	Predictive analytics and automated evaluation may reinforce inequalities or ignore atypical learners	Develop forward-looking frameworks that anticipate unintended consequences; safeguard against discriminatory or exclusionary practices

Procurement & Vendor Accountability	Outsourcing to third-party platforms risks data security and pedagogical autonomy	Introduce certification processes for vendors; require transparency, accessibility, and ethical data use as procurement criteria
Responsible Innovation Paradigm	Technologies evaluated only on efficiency/engagement, ignoring social impact	Redefine evaluation criteria to include societal and ethical impacts; scrutinize values and assumptions embedded in VR/XR/AI tools

Learner Agency and Personalization

While educational systems begin integrating disruptive technologies such as VR, XR, and AI into classrooms, the concept of learner agency emerges not only as a pedagogical aspiration but as a structural necessity. While traditional approaches often center on uniformity, the adoption of immersive and intelligent technologies appears to open new paths for differentiated learning journeys that adapt to individual learners' profiles, needs, and contexts. However, this potential is accompanied by inherent tensions: personalization may amplify autonomy, but it can also consolidate pre-existing inequalities or biases if left unregulated.

The brainstorming sessions held across different countries as part of the e-DIPLOMA project reflect a broad consensus on the relevance of adaptive systems and learner-driven models. Numerous proposals focus on enabling students to exercise greater control over the pace, sequencing, and content of their learning: "University classes usually give the same material to everyone, even though we all learn at different speeds. Also, getting feedback on assignments can take a long time, and grading isn't always consistent... I know that with machine learning, we could build a system that gives us custom learning paths and quicker feedback. It would make the learning process more engaging, and grading would feel more objective and transparent". Several contributors, particularly from student and teacher profiles, emphasized the importance of learning environments that support agency without creating the illusion of freedom in systems that remain rigid or opaque. In this sense, flexibility should not be mistaken for ambiguity, nor personalization for unchecked automation.

One key area identified was the design and implementation of **adaptive learning pathways** supported by AI-driven tools. Participants proposed systems that adjust based on learners' progress, preferences, and even emotional states: "AI has the capability to detect subtle emotional cues in text that might be missed by manual analysis. Early intervention in mental health issues has been shown to be highly effective in improving student well-being and academic outcomes". At the same time, some cautioned that such personalization must remain pedagogically grounded. Algorithms should not merely optimize for efficiency or engagement but align with long-term educational values. It was noted that adaptive systems, if poorly designed, may unintentionally steer learners toward pre-defined tracks, limiting rather than expanding their intellectual horizon.

Several proposals suggested embedding **reflective practices and metacognitive scaffolding** within VR, XR, and AI environments. Rather than positioning students as passive recipients of automated feedback, immersive systems could be leveraged to enhance learners' awareness of their learning processes. For instance, VR/XR modules might incorporate prompts that guide learners to reflect on their decision-making, explore alternative strategies, or revisit prior experiences from new perspectives. These approaches appear to foster a deeper sense of co-responsibility and ownership in learning, moving beyond the consumption of content. This is what participants had to contribute on the matter of developing such an important supportive skill as time management: ”It is important to ensure that such tools support rather than replace students’ development of time management skills. AI-based schedulers should be scaffolded to promote learner self-regulation and goal-setting. It is important to recognize that time management is a core skill in effective learning, especially in online environments. AI can play a significant role in helping students develop this skill by providing personalized study plans, reminders, and feedback on learning habits. In the future, intelligent systems could assist learners in setting realistic goals, identifying procrastination patterns, and managing workload more efficiently—thereby improving not just academic success but also lifelong learning competencies.”

Teacher and educator voices also drew attention to the need for **human-in-the-loop personalization**. While automated systems can offer valuable insights and adaptations, the final responsibility for shaping learning trajectories should remain with educators who understand students' social, emotional, and cultural contexts. This approach supports not only the agency of learners but also the professional autonomy of teachers, ensuring that personalization does not become a mechanism for managerial control or pedagogical outsourcing.

Interestingly, some proposals advocated for **student participation in the co-design of VR, XR and AI tools**. This vision of agency transcends consumption or interaction, proposing that learners themselves can contribute to the shaping of the technological tools that affect them. By including students in iterative design processes and feedback loops, educational institutions may cultivate a culture of empowerment and digital citizenship. It was also mentioned during brainstorm sessions that co-creation practices can have intergenerational dimensions and be beneficial both for younger learners and the elderly, who might experience loneliness and isolation. This might be achieved through cooperative gamification: ”A carefully designed game could be a very effective instrument to expose both youngsters and the elderly to suspicious or malicious situations and bring about a variety of learning moments. Such a game would bring together both groups, encouraging young people to help the elderly get along with digital technologies, and encouraging the elderly to take on a leadership and support role in developing the young person's online experience. In short, playing in such an intergenerational context overcomes serious mutual handicaps and contributes to combat loneliness.”

Nevertheless, challenges remain. The data from the brainstorming sessions suggest that personalization efforts are often concentrated in well-resourced contexts. Participants from underfunded regions voiced concern that adaptive learning systems are rarely implemented equitably, and when they are, they may not reflect the linguistic or cultural diversity of the student population. This asymmetry risks reinforcing the digital divide under the guise of individualization.

Finally, ethical considerations around learner profiling surfaced in multiple contributions. There was concern that personalization based on behavioral tracking or performance analytics may inadvertently create self-fulfilling prophecies. If algorithms predict success or failure, and educational opportunities are allocated accordingly, then learners may be locked into trajectories shaped by early data rather than evolving potential. It appears crucial to design personalization systems that remain open, reversible, and transparent.

In conclusion, learner agency and personalization stand out as both a promise and a responsibility in the integration of VR, XR and AI in education. The proposals collected during the e-DIPLOMA brainstorming sessions suggest a growing awareness of the nuanced ways in which technologies can support — or constrain — autonomy. The challenge lies in designing systems that adapt to learners, without constraining them; that provide pathways, without predetermining them. Achieving this balance requires careful governance, continuous human oversight, and sustained engagement with students as co-creators in the educational process.

Table 6. Learner Agency and Personalization in VR/XR/AI Education

	Stakeholder Concerns	**Proposed Solutions / Recommendations**
Adaptive Learning Pathways	Risk of personalization being efficiency-driven; algorithms may push learners into narrow tracks	Design AI systems that adapt to progress, preferences, and emotional states but remain pedagogically grounded; align adaptation with long-term educational values
Agency vs. Illusion of Freedom	Systems may appear flexible but remain rigid or opaque	Ensure personalization supports authentic learner control over pace, sequencing, and content; avoid ambiguity or hidden constraints
Reflective & Metacognitive Practices	Learners risk becoming passive recipients of automated feedback	Embed reflective prompts and metacognitive scaffolding in VR/XR/AI tools to enhance awareness, encourage strategy exploration, and deepen ownership of learning
Human-in-the-Loop Personalization	Over-automation could erode teacher autonomy and student support	Keep educators central in decision-making; use AI insights to inform, not replace, teachers' professional judgment; integrate social, cultural, and emotional contexts
Student Co-Design & Participation	Learners treated as consumers rather than contributors	Involve students in iterative design, feedback, and testing processes to foster empowerment and digital

		citizenship
Equity & Access	Adaptive systems more common in well-resourced contexts; neglect of linguistic/cultural diversity	Ensure equitable implementation across regions; adapt systems for diverse languages and cultural contexts; address structural inequities in access
Overarching Message	Personalization can empower but also constrain learners	Develop systems that adapt without predetermining; balance autonomy with oversight; embed governance and continuous student engagement

Digital Sovereignty and Public Infrastructure

Education systems across Europe deepen their engagement with immersive technologies and intelligent automation, and a parallel conversation has emerged regarding control over the digital ecosystems that mediate learning. The brainstorming sessions conducted as part of the e-DIPLOMA project captured growing concern among educators, researchers, and institutional actors about the long-term implications of reliance on proprietary platforms and commercially driven infrastructures. While these tools have often enabled rapid innovation and scalability, they may also introduce structural dependencies that limit institutional agency and restrict public oversight.

In several national brainstorming sessions, participants voiced discomfort with the increasing entrenchment of large private technology providers in core educational functions. The suggestions they advanced converge on a call for **strengthening public capacity in digital infrastructure**, particularly in areas related to immersive content delivery, learning data storage, and artificial intelligence deployment. This does not necessarily imply wholesale rejection of private-sector partnerships, but it does suggest that public authorities should develop alternatives where critical control, equity, and transparency are at stake.

A number of contributors proposed **investments in open-source platforms** that could serve as shared public goods. Current AI tools in education are often expensive, closed-source, and designed without sufficient alignment to public education needs. Many schools across Europe, especially in underserved regions, cannot afford commercial tools. Open-source AI can lower barriers to adoption, promote customization, and foster transparency. Open-source platforms, it was argued, might allow for greater adaptability to local curricular needs, enable participation in tool development by educators, and ensure long-term sustainability beyond commercial product cycles. Furthermore, open standards appear to be better aligned with the goals of inclusion, accessibility, and interoperability across national systems. As it was stated at the sessions: “Many teaching institutes use proprietary software stacks (including operating systems) that can require large financial investment and create a barrier for the students if these are not provided. On the other hand, nowadays open-source software is competitive in many areas and commonly used by both individuals and companies.”

Related to this is the idea of building **public repositories for VR/XR content**, which may support equitable access to high-quality immersive experiences without placing additional financial burdens on schools or families. Teachers, researchers, and technologists could contribute to these repositories collaboratively, with validation mechanisms that maintain educational quality. Some proposals even envisioned transnational cooperation, where member states might share resources and tools under a governance model that ensures fair contribution and access.

The issue of **cloud infrastructure sovereignty** was also raised by participants with expertise in educational IT management. In the current landscape, many institutions depend on servers and services hosted abroad, often under data jurisdictions that offer limited protection for educational records and student privacy. To address this vulnerability, proposals encouraged national or regional investments in secure, education-specific cloud services that are governed by public institutions or consortia. While this may require substantial initial investment, it appears to be viewed as a necessary step toward ensuring long-term autonomy and resilience.

Some stakeholders highlighted that **digital sovereignty is not only a technical or legal issue**, but also a pedagogical one. The platforms and systems educators rely on shape what is visible, measurable, and valued in learning. If personalization algorithms or analytics dashboards are designed according to commercial logic, they may incentivize narrow forms of success or disengage learners who do not conform to predefined patterns. Public infrastructure, on the other hand, may offer more room for co-design, experimentation, and alignment with democratic values.

At the same time, the feasibility of these proposals appears to depend heavily on policy coordination and institutional readiness. Some participants expressed concern about the fragmentation of efforts across levels of governance. For public infrastructure projects to succeed, it seems essential that national education ministries, regional authorities, and universities collaborate to develop coherent frameworks, sustainable funding models, and inclusive development processes.

Ultimately, the discussions across countries point to a broader shift in thinking: digital transformation in education should not be equated with procurement. Instead, it is likely to require capacity-building in digital governance, investment in public knowledge infrastructures, and a reassertion of the public mission of education in the digital age.

Table 7. Digital Sovereignty and Public Infrastructure in VR/XR/AI Education

	Stakeholder Concerns	**Proposed Solutions / Recommendations**
Dependence on Proprietary Platforms	Reliance on large private tech providers creates structural dependency; weakens institutional agency and public oversight	Strengthen public capacity in digital infrastructure; develop public alternatives in critical areas (content delivery, data storage, AI deployment)
Open-Source & Shared Platforms	Commercial products limit adaptability and sustainability	Invest in open-source platforms as public goods; allow local curricular adaptation and educator participation in tool

		development; ensure interoperability
Public Repositories for VR/XR Content	Access to high-quality immersive content often tied to cost, reinforcing inequalities	Build public repositories for VR/XR materials; enable collaborative contributions from teachers, researchers, and technologists; ensure quality validation; explore transnational cooperation
Cloud Infrastructure Sovereignty	Dependence on foreign servers risks data protection and student privacy	Invest in secure national/regional education-specific cloud services; govern through public institutions or consortia to ensure autonomy and resilience
Pedagogical Implications of Sovereignty	Commercial platforms shape what is valued/measured in learning, risking narrow definitions of success	Public infrastructure should enable co-design, experimentation, and alignment with democratic and educational values
Policy Coordination & Governance	Fragmentation across governance levels undermines large-scale projects	Foster collaboration among ministries, regional authorities, and universities; develop coherent frameworks, sustainable funding, and inclusive processes

Interoperability and Standards

As extended reality (XR), virtual reality (VR), and artificial intelligence (AI) technologies continue to be integrated into education, the issue of interoperability appears increasingly central. While innovation can thrive in fragmented ecosystems, the long-term sustainability, scalability, and accessibility of immersive learning tools depend significantly on shared standards and open architectures. Without these, educational institutions may find themselves locked into proprietary systems that are difficult to maintain or integrate with evolving pedagogical practices.

Insights gathered from the stakeholder brainstorming sessions suggest a growing awareness of the risks associated with technological silos. Several contributors expressed concern that VR, XR and AI deployments, if developed in isolation, might inhibit cross-platform collaboration or content reuse. This fragmentation could slow innovation and create unnecessary barriers to adoption, particularly in resource-constrained settings. Some proposals imply a preference for promoting open standards that allow educational content to flow freely between different platforms and institutions.

There is also a recognition, though not always explicitly stated, that interoperability is not solely a technical concern. It encompasses pedagogical, ethical, and administrative dimensions as well. For example, if different platforms use incompatible data formats, it becomes challenging to implement consistent assessment models or track learning outcomes across systems. Similarly, the lack of standards for describing learning objects, interaction patterns, or user experience metrics may undermine attempts to develop evidence-based educational practices.

A number of stakeholders advocated for support mechanisms at both national and EU levels to coordinate efforts toward standardization. These could include dedicated working groups, public investment in open-source repositories, and policy instruments that incentivize the use of interoperable formats. Some proposals also touched on the need for metadata standards for XR content, especially in relation to accessibility features, privacy protection, and curriculum alignment. This may suggest an emerging consensus that interoperability is not merely about system compatibility, but also about ensuring that immersive learning tools can be effectively integrated into diverse educational environments.

In addition, the question of data portability arose in several discussions, often in connection with student agency and institutional autonomy. Participants noted that if learning analytics data or AI-based learner profiles are tied to specific vendors, institutions may struggle to extract value from these tools over time. This could erode trust in educational technologies and raise ethical questions about surveillance, bias, or long-term data ownership. Developing frameworks that enable secure, user-controlled transfer of data between platforms appears to be a priority, albeit one that still lacks concrete implementation pathways.

Maintaining and updating digital infrastructure was also cited as a challenge in relation to interoperability. Several proposals implicitly pointed to the need for capacity-building at the local level, so that IT departments, teachers, and school leaders can manage transitions between systems without losing pedagogical continuity. This need becomes more acute as hybrid learning models and distributed classroom environments grow more common.

The broader implication is that educational policy should not only encourage the uptake of VR, XR and AI but also provide structural support for their responsible integration into existing systems. Establishing a European framework for interoperability in educational technology—potentially linked to initiatives like the European Digital Education Hub—could serve as a stabilizing mechanism in an otherwise rapidly changing technological landscape.

In sum, the reflections of stakeholders underline the importance of designing VR/XR/AI systems that are modular, adaptable, and aligned with pedagogical realities. While no single standard is likely to fit all contexts, coordinated efforts to ensure cross-platform compatibility, open licensing, and ethical data practices can make the difference between isolated experiments and systemic transformation. Building for interoperability, it seems, is not just a technical task, but a policy imperative.

Table 8. Interoperability and Standards in VR/XR/AI Education

	Stakeholder Concerns	**Proposed Solutions /**

		Recommendations
Fragmentation & Proprietary Lock-In	Risk of technological silos; difficulty reusing content across platforms; vendor lock-in limits flexibility and innovation	Promote open standards and shared architectures; ensure content can flow freely across platforms and institutions
Pedagogical & Ethical Dimensions	Incompatible formats hinder consistent assessment and tracking; lack of standards weakens evidence-based practices	Develop standards for learning objects, interaction patterns, and UX metrics; embed accessibility, privacy, and curriculum alignment in interoperability frameworks
National & EU-Level Coordination	Isolated initiatives lack coherence; absence of large-scale governance mechanisms	Establish dedicated working groups, public investment in open repositories, and EU-level policy instruments incentivizing interoperable formats
Metadata & Accessibility Standards	Lack of systematic metadata for VR/XR content undermines usability and inclusion	Introduce metadata standards addressing accessibility, privacy safeguards, and curricular integration
Data Portability & Ownership	Learning analytics tied to vendors reduce institutional autonomy; ethical concerns over surveillance and bias	Create frameworks for secure, user-controlled transfer of learner data; strengthen institutional rights over educational data
Local Capacity-Building	IT staff, teachers, and leaders lack resources to manage system transitions; risk of losing pedagogical continuity	Invest in local training and support structures for managing interoperability and hybrid learning environments
European Policy Frameworks	Current policies encourage uptake but neglect integration; lack of stabilizing mechanisms	Establish a European interoperability framework (e.g., linked to European Digital Education Hub) to guide systemic adoption

Multi-Stakeholder Engagement and Participatory Policymaking

If one message resounded clearly across the e-DIPLOMA brainstorming sessions, it was that the transformation of education through VR, XR and AI cannot be achieved in isolation. While technological tools are evolving rapidly, the institutions that shape their adoption often lag, not because of a lack of intent, but due to limited coordination and weak feedback loops between the various groups involved. Designing policy in this space, therefore, appears to require not only expert consultation but also a broader opening up to those directly affected by educational technologies—teachers, learners, families, school leaders, developers, and administrators.

The structure of the brainstorming dataset itself reinforces this point. A wide array of stakeholders participated in the sessions, including students, educators, university staff, government representatives, private sector actors, and NGOs. Their contributions, although unequal in number, reflect a diversity of experiences, constraints, and priorities. For example, students and family representatives raised concerns about usability, wellbeing, and connectivity, often from a very practical standpoint. At the same time, institutional voices tended to highlight infrastructure, procurement, and long-term investment challenges. Industry participants brought attention to innovation timelines, integration support, and the need for clearer regulatory guidance.

Such variation, while not surprising, signals the importance of building institutional mechanisms that can capture and sustain these perspectives over time. One-off consultations, while valuable, are rarely enough. Several proposals in the dataset call for the establishment of ongoing advisory councils or cross-sector task forces at regional or national levels. These bodies would ideally include not only policymakers and experts, but also practicing teachers, students, and parents, especially from communities that are traditionally underrepresented in digital governance.

Some suggestions go further, proposing that educational institutions develop internal participatory structures—such as digital steering groups or student-led panels—that regularly feed into school or university decision-making. These initiatives may not always have formal authority, but they could help institutions remain attuned to lived realities and emerging tensions. For instance, a teacher-facing dashboard that is being piloted in one context might cause confusion or overload in another. Without structured feedback from users, such mismatches are likely to persist.

Another pattern emerging from the brainstorming sessions relates to the local nature of digital transformation. Participants from different countries and institutional settings often described highly specific constraints: outdated infrastructure in rural areas, patchy digital literacy among staff, conflicting policy mandates, or unstable procurement channels. While certain policy recommendations may seem universally desirable—such as fair access, privacy protection, or interoperability—their implementation often depends on deeply contextual factors. As such, some contributions argue for a shift away from top-down implementation models and toward more adaptive policy cycles that allow for experimentation, correction, and refinement over time.

The role of the private sector, too, attracted both optimism and concern. While companies offer valuable tools, training, and expertise, several participants voiced unease about vendor lock-in, opaque licensing terms, and limited responsiveness to classroom realities. A few suggestions propose clearer accountability mechanisms, including ethical charters for tech developers working with schools or procurement criteria that prioritize pedagogical fit and inclusive design. These perspectives suggest that public-private dialogue may need to evolve from transactional arrangements toward longer-term partnerships grounded in shared values and mutual transparency.

Encouragingly, there were also ideas for more horizontal engagement across educational institutions. Some contributors recommended regional alliances or communities of practice in which schools, universities, and vocational centres could exchange lessons learned, co-develop resources, or test new approaches together. This kind of peer collaboration may help reduce the implementation gap between leading and lagging institutions, while also building shared capacity for critical reflection on digital transformation processes.

Ultimately, if VR, XR and AI are to become more than pilot projects or novelty tools, their integration into education will require sustained, inclusive, and reflexive policymaking. This does not mean aiming for consensus at all costs—tensions and trade-offs are inevitable—but rather creating spaces where divergent views can be expressed, debated, and translated into action. In this light, multi-stakeholder engagement should not be seen as an accessory to policymaking, but as a foundational practice for navigating the complex educational futures that lie ahead.

Table 9. Multi-Stakeholder Engagement and Participatory Policymaking in VR/XR/AI Education

	Stakeholder Perspectives	**Proposed Mechanisms / Recommendations**
Need for Broad Participation	Students, teachers, families emphasized usability, wellbeing, connectivity; institutions focused on infrastructure and investment; industry highlighted innovation cycles and regulatory clarity	Policy design must include diverse groups beyond experts; avoid isolated decision-making
Institutional Mechanisms	One-off consultations seen as insufficient; lack of structured feedback loops	Establish ongoing advisory councils or cross-sector task forces including teachers, students, families, and policymakers
Internal Participatory Structures	Teachers and learners often excluded from decision-making on tools	Create digital steering groups, student panels, or feedback dashboards within schools/universities
Local Contextual Constraints	Challenges varied by country/region: rural infrastructure gaps, low digital literacy, unstable procurement	Shift from top-down implementation to adaptive policy cycles with experimentation, correction, and refinement
Role of Private Sector	Companies provide tools and expertise but raise concerns about vendor lock-in, opaque contracts, weak classroom fit	Develop accountability mechanisms (ethical charters, transparent procurement, criteria for pedagogical and inclusive design)

Horizontal Engagement	Institutions often work in isolation; lessons not widely shared	Build regional alliances or communities of practice for co-development, peer exchange, and joint testing

Psychological Wellbeing and Cognitive Load Management

As VR, XR, and AI technologies begin to reshape educational practice, concerns around psychological well-being and cognitive load are becoming increasingly difficult to ignore. While immersive environments can captivate learners and enhance engagement, they also carry risks that are not yet fully understood. The enthusiasm surrounding digital innovation is accompanied by a quieter but persistent set of worries about overstimulation, fatigue, prolonged screen exposure, and the unintended effects of artificial agents on learner motivation and emotional regulation. As one educator highlighted, “Digital learning can increase screen time, isolation, and stress for both students and educators. Without mental health support, these challenges may affect performance, engagement, and long-term well-being. Digital tools can help address this crisis, but only if they are backed by thoughtful policy and support. Mental health services in schools are limited or unevenly available across regions. Digital learning environments rarely include mental wellness features or check-ins. Educators are not consistently trained to recognize or support digital burnout or distress. Cultural stigma around mental health can limit access and openness. Current education systems often treat mental health as a side issue rather than a core part of a digital education strategy. This leaves students and teachers vulnerable to stress, fatigue, and burnout without structured support.”

These concerns surfaced repeatedly throughout the brainstorming sessions. Though the number of suggestions under this theme was lower than in some other domains, their urgency stood out. Participants spoke of students feeling overwhelmed during long XR sessions, teachers unsure of how to regulate cognitive effort, and families raising alarms about increased screen time without adequate movement or social interaction. Several contributions asked whether current guidelines for safe screen use are sufficient when applied to immersive technologies, which often engage the body and senses more intensely than traditional digital tools.

This discomfort is not unfounded. Immersive systems, whether through VR headsets or augmented layers, can easily blur the boundaries between learning and sensory overload. If the content is poorly paced or the interface is overly complex, learners may disengage or experience disorientation. Attention span, which is already fragile in digital contexts, may be further strained in VR/XR environments unless careful consideration is given to design flow, visual ergonomics, and cognitive sequencing. One of the major concerns was the lack of physical activity dictated by the nature of immersive digital environment: “To address childhood inactivity, schools and communities should integrate Augmented Reality (AR) technology into physical activity programs, making exercise engaging, fun, and inclusive.”

The data collected during previous stages reflects growing awareness of these issues, especially among educators and student participants. Several proposals suggest limiting the duration of immersive activities to manageable timeframes, particularly for younger learners. Others recommend alternating between immersive and screen-free periods, allowing learners to process information in a less intense format. A few advocate for integrating physical movement into digital learning routines, whether through embodied interaction or scheduled outdoor time. The outdoor time can also be improved with the help of the disruptive technologies, as they might play a critical role in addressing " issues such as obesity, smoking, and drug use, and encourage active lifestyles. Introducing AR-based physical activities can enhance these programs by providing interactive and engaging ways for students to participate in physical exercises". These proposals do not reject XR, but rather call for its integration into a more balanced ecosystem of learning modalities.

Another dimension highlighted by participants relates to teacher capacity. Many educators, especially those new to immersive tools, appear unsure of how to detect signs of overload in students or themselves. Recommendations include professional development modules on cognitive ergonomics, the psychological impact of avatars and virtual agents, and early indicators of mental fatigue. Some also call for creating "digital wellness coordinators" or assigning staff to monitor and support student wellbeing during prolonged VR, XR, or AI-based learning cycles.

Several proposals go further by suggesting that well-being should not be treated as an afterthought but rather as a key metric in evaluating VR/XR/AI implementation. This might involve integrating affective indicators into system dashboards or conducting regular learner feedback loops focused on psychological comfort and perceived load. While technical feasibility may vary across contexts, the message is clear: systems that ignore the emotional and cognitive cost of immersion may undercut their pedagogical promise. Among the solutions is the creation of instruments integrated into learning platforms that can identify mental health problems independently of human factor: "Build mental health tools and check-ins directly into learning platforms and teacher workflows, so support becomes a natural part of education. It blends prevention, awareness, and support into the core of digital education. It reaches more people and creates a safer, healthier environment for learning and teaching."

Importantly, these discussions extend beyond individual learners to the collective atmosphere of educational spaces. Participants voiced concern that environments saturated with intelligent systems could become depersonalized or performance-driven, heightening anxiety and reducing intrinsic motivation. In response, some suggestions advocate for human-centered interaction protocols, slower feedback cycles, and opportunities for peer reflection and collaborative debriefing. The goal, it seems, is to preserve the emotional and social texture of learning even as technology transforms its structure.

There is also a call for greater alignment between design teams and psychological experts. Very few VR/XR developers working in education currently consult specialists in developmental psychology or mental health. Encouraging interdisciplinary cooperation—especially in the prototyping and pilot phases—could mitigate risks before they become systemic. Several participants proposed co-design approaches that involve learners not only as testers but as informants on comfort, attention, and emotional resonance.

Although research on long-term cognitive and emotional effects of VR/XR in education remains limited, the precautionary principle suggests that careful scaffolding is needed. Schools, ministries, and developers may need to move away from one-size-fits-all rollouts and toward more iterative and responsive implementation cycles. In contexts where vulnerability is already high—such as among neurodivergent learners or students experiencing trauma—the stakes of poor design are even higher.

Taken together, these insights suggest that managing psychological wellbeing and cognitive load is not a peripheral issue but a central pillar of responsible digital transformation. The e-DIPLOMA project, by surfacing these concerns through participatory channels, reinforces the idea that immersive learning is not just a technological opportunity, but a human experience. Its success, in the long run, will likely depend not only on what XR and AI can do, but on how well they are attuned to the complex rhythms of attention, emotion, and human development.

Table 10. Psychological Wellbeing and Cognitive Load in VR/XR/AI Education

	Stakeholder Perspectives	**Proposed Mechanisms / Recommendations**
Overstimulation & Fatigue	Students report feeling overwhelmed in long VR/XR sessions; families worry about extended screen time; teachers struggle to regulate cognitive effort	Limit duration of immersive activities; alternate VR/XR with screen-free time; integrate physical movement or outdoor activities
Cognitive Overload & Attention	Poor sequencing or overly complex interfaces risk disorientation, frustration, or disengagement; VR/XR immersion intensifies sensory input, stretching already fragile attention spans	Design learning flow carefully to balance stimulation and focus; apply visual ergonomics (e.g., reducing clutter, adjusting brightness); scaffold activities to gradually increase complexity; combine VR/XR with low-stimulus reflection periods
Teacher Capacity & Support	Many educators lack training to recognize signs of overload, stress, or disengagement; uncertainty about managing avatars, AI tutors, or virtual agents in ways that support mental health	Provide professional development on cognitive ergonomics, psychological impacts of avatars/agents, and early signs of fatigue; establish school roles such as “digital wellness coordinators” to monitor student wellbeing during VR/XR/AI use
Wellbeing as a Metric	Wellbeing typically treated as secondary to efficiency or engagement; lack of systematic monitoring of emotional and cognitive costs	Incorporate affective indicators (e.g., stress, frustration, motivation) into analytics dashboards; conduct learner surveys and participatory evaluations to monitor comfort and perceived load; treat wellbeing as a core criterion in VR/XR/AI implementation
Learning Atmosphere	Fear that AI-, VR- and XR-driven	Implement human-centered

	environments could become depersonalized, overly performance-focused, or anxiety-inducing	interaction protocols; slow down feedback cycles to reduce pressure; provide structured opportunities for peer reflection, collaborative debriefing, and social interaction alongside immersive tasks
Expert Involvement	Developers rarely consult psychologists or mental health specialists during design; risk of overlooking long-term developmental effects	Involve specialists in developmental psychology and mental health at prototyping stage; co-design tools with learners as active informants on comfort, attention, and emotional resonance; embed ethical review in pilot projects
Equity & Vulnerability	Risks disproportionately affect neurodiverse learners, those with sensory sensitivities, or students experiencing trauma	Customize VR/XR/AI use for vulnerable groups (e.g., adjustable sensory inputs, personalized pacing); avoid one-size-fits-all deployment; adopt iterative rollouts with feedback loops that allow for rapid adaptation

Capacity Building for Systemic Change

The transition to VR, XR and AI-enhanced education environments is unlikely to succeed without a deliberate investment in institutional readiness. While training individual educators remains important, several proposals from students, families, and community leaders stress that capacity must be developed at the **system level**—not just through isolated workshops or short-term upskilling courses.

Participants across brainstorming sessions emphasized the necessity of **embedding VR/XR/AI education into the DNA of teacher preparation institutes**. For example, multiple suggestions advocate for including AI and VR/XR modules in teacher certification programs, particularly in fields like computer science, design, and special education: “Create a multidisciplinary body that includes experts in education, computer science, psychology, and other fields, responsible for issuing the certification that defines the parameters used to assess a user's proficiency in immersive technologies”. One representative pointed out that “teacher training institutes should add AI/VR modules as part of their mandatory curriculum,” suggesting that without such baseline preparation, technological integration will remain superficial and uneven.

Several entries also recommend the development of **multifunctional Smart Labs** in schools, but not merely as tech installations. These spaces were envisioned as hubs where teachers, IT personnel, and students collaborate, train, and co-develop practices that reflect real classroom challenges. In some cases, proposals highlighted the value of setting up “national ‘Tech for All Classrooms’ campaigns” to support cross-institutional mentoring, public-private partnerships, and community involvement.

Interestingly, capacity building is not limited to pedagogy alone. A number of contributors called for **leadership training for school administrators**, particularly in managing infrastructure upgrades, digital procurement, and the ethical oversight of emerging technologies. They warned that without informed decision-makers at the helm, investments in VR/XR/AI may lead to fragmentation and inefficiencies.

Some participants raised concerns about **over-reliance on individual initiative**, especially in under-resourced settings where systemic support is weak or absent. For them, the question was not just how to train teachers, but **h**ow to redesign institutional pathways so that VR/XR/AI integration becomes part of an ongoing, **evidence-informed development cycle**.

Finally, a few proposals suggested integrating **competence-based evaluation metrics** into professional development frameworks, allowing educators to progress and be recognized based on their demonstrated ability to use and adapt VR/XR/AI tools effectively.

In sum, the direction is clear: systemic capacity building must extend beyond isolated efforts and address the institutional, pedagogical, and infrastructural layers of change. It appears essential to develop long-term strategies that **link individual skills with institutional transformation**, support experimentation, and foster leadership for a digital education future.

Table 11. Capacity Building for Systemic Change in VR/XR/AI Education

	Stakeholder Perspectives	**Proposed Mechanisms / Recommendations**
System-Level vs. Individual Training	Risk that VR/XR/AI adoption remains fragmented if training is limited to ad-hoc workshops or individual upskilling	Build capacity at institutional and systemic levels; embed VR/XR/AI education into teacher training institutes and certification programs
Teacher Preparation & Certification	Without baseline preparation, integration will remain superficial and uneven	Include VR/XR/AI modules in teacher certification (esp. computer science, design, special education); make AI/VR training part of mandatory curricula for new teachers
Smart Labs as Hubs	Labs seen as underused when treated as standalone tech spaces	Develop multifunctional Smart Labs for collaborative training, experimentation, and co-design among teachers, IT staff, and students
Community &	Concern about isolated	Launch national “Tech for All”

Cross-Institutional Support	initiatives that lack momentum or inclusivity	campaigns; promote cross-institutional mentoring, public-private partnerships, and community engagement
Leadership & Administration	Administrators often unprepared for managing procurement, infrastructure, and ethical challenges	Provide leadership training for school leaders on infrastructure management, digital procurement, and oversight of emerging technologies
Equity & Structural Weaknesses	Under-resourced schools cannot rely solely on individual teacher initiative	Redesign institutional pathways to ensure ongoing, evidence-based professional development; provide systemic support in disadvantaged Contexts
Professional Development Metrics	Current frameworks rarely recognize competence in digital integration	Integrate competence-based evaluation into teacher development systems, rewarding effective VR/XR/AI use and adaptation

Sustainability and Environmental Considerations

Environmental considerations surrounding VR, XR, and AI integration in education have surfaced gradually but meaningfully throughout the brainstorming sessions. While not the most frequently discussed theme, the environmental dimension appeared repeatedly across different stakeholder groups, especially among educators, students, and family representatives. Concerns ranged from energy consumption to e-waste, suggesting a growing awareness that digital transformation must be ecologically responsible, not just technologically ambitious.

Several participants highlighted the importance of **energy efficiency** when selecting VR, XR, and AI hardware. Rather than treat these tools as neutral inputs, some educators and technical experts advocated for the inclusion of **low-power consumption requirements** in public procurement procedures. Devices used in learning environments, they argued, should meet not only pedagogical criteria but also environmental performance benchmarks. Suggestions included requiring lifecycle energy data from vendors and prioritizing hardware designed for minimal energy draw during standby and active use.

Another frequently raised concern related to the **end-of-life management** of VR, XR and AI equipment. Proposals called for more structured approaches to reuse, repair, and recycling. One teacher suggested forming partnerships with local repair shops to extend the lifespan of devices, while a student voiced the need for **school-based e-waste collection systems** to handle old headsets and related peripherals. These contributions appear to reflect a shared concern that schools, often left out of broader circular economy frameworks, should begin modeling sustainable digital practices themselves.

Rather than relying solely on one-to-one device distribution, a number of stakeholders proposed more **resource-sharing infrastructures**, especially in rural or economically disadvantaged areas. The idea of regional Smart Labs or mobile immersive units gained traction in several sessions. Not only would this model reduce equipment redundancy and cost, it would likely decrease the carbon footprint of widespread VR/XR adoption. One policymaker noted that pooling immersive resources might also improve access and mitigate inequalities between schools.

Calls for **institutional accountability** also emerged. Participants recommended that ministries or school boards conduct **environmental impact assessments** before scaling up VR, XR or AI deployments. This would involve tracking metrics such as electricity usage, device turnover rates, and the sustainability credentials of tech suppliers. Transparency in these matters, they argued, could both inform better decisions and reinforce public trust.

Awareness, however, remains uneven. While some suggestions reflected a detailed understanding of ecological risks—such as the environmental cost of cloud computing in AI applications—others pointed only vaguely to the need for "sustainability in digital education." This unevenness suggests a need for **capacity building on green digital practices**. Teacher training, curriculum content, and student-led sustainability initiatives were all named as possible vectors for building a stronger environmental culture around digital education.

To move forward, e-DIPLOMA stakeholders may need to integrate **sustainability as a design principle** rather than a post-implementation concern. This could involve choosing open hardware standards to enable easier upgrades, investing in modular devices, or even supporting research into **biodegradable components** for educational technology. Aligning infrastructure investments with climate goals would further underscore the program's long-term vision.

Sustainability in digital transformation is unlikely to resolve itself without active governance. The data suggests a growing consensus that schools should not merely adopt digital tools—they should **adopt them responsibly**. The strategic ambition of e-DIPLOMA, if it is to remain future-facing, will benefit from treating environmental sustainability not as an optional add-on, but as a condition of innovation itself.

Table 12. Sustainability and Environmental Considerations in VR/XR/AI for Education

	Stakeholder Perspectives	**Proposed Mechanisms / Recommendations**
Energy Efficiency	High energy consumption of VR/XR/AI devices; risk of ignoring environmental footprint in procurement	Include low-power requirements in procurement policies; demand lifecycle energy data from vendors; prioritize devices with low standby and active energy draw
E-Waste & Device Lifecycle	Lack of structured systems for managing obsolete headsets, peripherals, and AI hardware	Develop school-based e-waste collection; partner with local repair shops to extend device lifespan; encourage

		repair/reuse before disposal; integrate schools into circular economy initiatives
Resource Sharing Models	Concerns about redundant one-to-one device distribution, especially in rural/low-resource contexts	Establish regional Smart Labs or mobile immersive units; share VR/XR/AI hardware across networks of schools; reduce carbon footprint through collective infrastructure use
Institutional Accountability	Limited oversight of ecological consequences in digital rollouts	Require environmental impact assessments before large-scale adoption; track electricity consumption, device turnover, and supplier sustainability; ensure public reporting for transparency
Awareness & Capacity Building	Uneven understanding of ecological risks (e.g., energy demands of cloud AI, server farms)	Include “green digital practices” in teacher training; embed sustainability in curricula; support student-led sustainability initiatives in schools
Design for Sustainability	Current devices often short-lived, hard to upgrade, or tied to proprietary systems	Promote modular and open hardware standards; support research into biodegradable or recyclable components; invest in devices designed for repairability and longevity
Alignment with Climate Goals	Risk of digital transformation conflicting with ecological commitments	Ensure national/local infrastructure investments align with climate strategies; integrate sustainability as a core design principle rather than a post-implementation add-on

3.4 Policy Recommendations Structured by Level of Intervention

The participatory work carried out in WP6 showed that meaningful digital transformation in education depends on coordinated action at every level of governance. The following recommendations turn the insights gathered from stakeholders into practical measures that can guide future policy. They are organized by level of intervention (European, national, regional, and local) to show how responsibilities and resources can come together to support a more coherent and inclusive approach to integrating XR and AI in education.

Objective 1: Ensure equitable and sustainable digital transformation across European education systems

Level	Concrete Action	Responsible Actors	Expected Impact
EU	Establish a European Observatory on VR/XR/AI in Education to collect, compare, and disseminate data on access, inclusion, and innovation.	European Commission (DG EAC), European Schoolnet	Shared evidence base; alignment of national strategies; reduced fragmentation.
National	Introduce targeted digital infrastructure funds for under-resourced schools and universities.	Ministries of Education, Innovation, and Finance	Reduced regional disparities; sustainable access.
Regional	Set up Digital Learning Hubs that connect schools, teacher training centers, and innovation clusters.	Regional Education Authorities	Stronger local innovation ecosystems.
Local/Institutional	Promote shared-use models for XR labs and resource pooling between nearby schools.	Local authorities, school consortia	Efficient use of public resources; inclusive access.

Objective 2: Strengthen teacher capacity and institutional readiness for XR/AI adoption

Level	Concrete Action	Responsible Actors	Expected Impact
EU	Support a European network for teacher digital innovation fellowships.	European Commission (Erasmus+, Horizon Europe)	Increased professional mobility and cross-border learning.

National	Include VR/XR/AI training in teacher certification and lifelong learning frameworks.	Ministries of Education, Teacher Training Agencies	Mainstreamed competence in digital pedagogy.
Regional	Co-fund local micro-credentials and mentoring schemes on immersive learning.	Regional authorities, HEIs	Sustainable peer-to-peer professional development.
Local/Institutional	Provide time allocation or workload recognition for teachers integrating XR/AI tools.	Universities, schools	Reduced burnout; higher engagement in innovation.

Objective 3: Embed inclusion, ethics, and accessibility in XR/AI education

Level	Concrete Action	Responsible Actors	Expected Impact
EU	Develop European guidelines for ethical and inclusive design of educational XR/AI systems.	European Commission, European Data Protection Board	Harmonised ethical standards; increased trust in AI in education.
National	Require accessibility audits for publicly funded VR/XR/AI educational projects.	National Ministries of Innovation/ Education	Compliance with inclusion principles; reduced bias.
Regional	Establish regional advisory boards on inclusion and ethics in EdTech innovation.	Regional Education Departments	Context-sensitive policy adaptation.
Local/Institutional	Co-design accessibility features with students with disabilities and special educators.	Schools, universities	More equitable and user-centered XR experiences.

Objective 4: Encourage innovation ecosystems and cross-sector collaboration

Level	Concrete Action	Responsible Actors	Expected Impact
EU	Create an annual European XR/AI Education Innovation Challenge.	European Commission, EIT Digital	Accelerated diffusion of scalable practices.
National	Incentivize joint ventures between EdTech start-ups and public education institutions.	Ministries of Economy / Education	Increased innovation capacity; reduced dependency on foreign vendors.
Regional	Provide seed grants for co-created VR/XR/AI projects involving local SMEs.	Regional governments	Strengthened local value chains; digital upskilling.
Local/Institutional	Establish innovation "sandboxes" for testing XR/AI prototypes in real classrooms.	Schools, teacher training centers	Iterative testing and faster learning cycles.

Chapter 4: Ethical Governance and Responsible Innovation in Digital Education

The e-DIPLOMA project approached the challenge of ethical governance in digital innovation from the outset with the conviction that ethics must guide innovation, not follow it. Introducing VR, XR, and AI into education without an explicit ethical framework risks reinforcing existing inequalities, eroding trust in institutions, or normalizing surveillance practices that compromise the learner's sense of agency. Conversely, when ethics is treated as a generative force rather than a constraint, it becomes a tool for inclusion, creativity, and empowerment. Ethical reflection helps ensure that technology serves the learner's development, rather than the other way around.

This perspective aligns with the broader principles of **Horizon Europe**, which frames all research and innovation around four core ethical values: **autonomy**, **justice**, **beneficence**, and **non-maleficence**. Autonomy protects the right of individuals to make informed choices about their participation and data. Justice ensures that the benefits and burdens of technological progress are distributed fairly across regions, genders, and social groups. Beneficence demands that innovation should produce measurable good—enhancing learning opportunities, accessibility, and social inclusion. Non-maleficence, finally, reminds institutions that enthusiasm for innovation must never come at the expense of safety, dignity, or psychological wellbeing.

Within e-DIPLOMA, these principles were not abstract ideals but concrete operational standards. Ethical review procedures, informed consent protocols, and transparent data management frameworks were embedded at every stage of the project's lifecycle. Researchers and educators worked together to ensure that learners' rights were respected, that participation was voluntary, and that the technologies tested reflected the diversity of European classrooms.

4.1 Ethics in Practice: Procedures and Safeguards Implemented in e-DIPLOMA

The ethical integrity of the e-DIPLOMA project was grounded in concrete procedures that guided all stages of its research and piloting. Each participating institution committed to applying shared ethical standards defined in the **Ethics Plan (D7.2)**, fully aligned with the Horizon Europe framework, and relevant national legislation. These safeguards were designed to protect participants' rights, strengthen transparency, and create conditions of trust for testing AI, XR, and other emerging technologies in education.

Human Participation and Informed Consent

All participants in e-DIPLOMA, including teachers, students, administrators, and other contributors, took part voluntarily and with a clear understanding of the project's goals and methods. They received **multilingual consent forms** explaining how their data would be used, what participation involved, and that they could withdraw at any moment without consequences. Special attention was devoted to the participation of minors, as several pilot activities took place in schools. Parental or guardian consent was obtained in every case, and teachers received guidance on how to explain the project in an age-appropriate way. During sessions that involved virtual or extended reality, educators were trained to observe learners for any signs of discomfort, disorientation, or fatigue. The duration of exposure was limited, and short reflection sessions were included afterwards to help students process their experiences. This approach placed psychological and physical well-being at the center of the project's activities.

Data Protection and Pseudonymisation

The project applied strict standards for handling personal data. All data were processed according to the GDPR principles of lawfulness, purpose limitation, and data minimization. Identifiable information was stored separately and replaced with pseudonymised identifiers, ensuring that no participant could be recognized.

Each partner institution used secure, access-controlled repositories to store data. Encryption, limited access, and regular audits maintained high levels of security. Participants were informed about the purpose of data collection, the length of storage, and the deletion procedures that would follow the project's completion. These measures guaranteed that privacy remained protected while research remained transparent and responsible.

4.2. Recommendations Towards a European Framework for Ethical VR/XR/AI Integration

Establishing an ethical foundation for XR and AI in education requires coordinated governance across all institutional and political levels. Effective oversight cannot rely solely on individual national initiatives or institutional practices; it needs a shared European framework that guarantees consistency, transparency, and accountability. The experience of e-DIPLOMA demonstrates that the successful adoption of emerging technologies depends on a well-structured system of responsibilities, dialogue, and continuous evaluation linking European, national, regional, and local actors.

At the European level, governance should build on existing frameworks such as the EU Artificial Intelligence Act, the Digital Education Action Plan (2021–2027), and the European Declaration on Digital Rights and Principles. At the **national level**, education ministries and government agencies play a key role in translating European principles into binding regulations. National policies could require **ethical impact assessments** for new digital tools in education, include **ethics and digital responsibility** in teacher training programs, and introduce **accreditation standards** for providers of AI and XR systems. Data protection authorities should also develop specialized guidance addressing the unique ethical and privacy risks of immersive technologies and algorithmic learning environments. This would ensure alignment between national practices and European standards.

At the **regional level**, authorities can bridge policy and practice by supporting context-sensitive implementation. Regional education agencies and innovation centers can coordinate **training for teachers and administrators**, help institutions design local ethics protocols, and encourage collaboration between schools, universities, and technology developers. These actors are well-positioned to identify local needs and pilot inclusive and accessible approaches that reflect regional diversity across Europe.

At the **local level**, the ethical dimension of digital transformation becomes tangible. Schools, universities, and training centers can establish **ethics committees or liaison officers** responsible for reviewing XR and AI activities, ensuring informed consent, and safeguarding equal access to technology. Integrating ethical reflection into teaching practices, curriculum design, and classroom dialogue helps students understand how algorithms, data collection, and digital systems affect learning and society. Local initiatives thus become the foundation for a broader culture of responsible innovation.

This layered approach turns ethics into a living practice. When European coordination, national regulation, regional adaptation, and local engagement operate together, they create a sustainable framework for integrating VR, XR and AI in education. Such a model ensures that technological progress supports human values, strengthens inclusion, and builds lasting public trust in digital transformation.

Policy Brief

Title: Strategic Policy Recommendations for Integrating VR/XR and AI in Education: A Comprehensive Framework for Adopting Disruptive Technologies at European, National, and Local Levels

Highlights:

- Education systems across Europe are seeking to integrate Extended Reality (XR/VR) and Artificial Intelligence (AI), but fragmented policy frameworks hinder equity, scalability, and sustained pedagogical value.

- Evidence from the e-DIPLOMA project proves the need for inclusive, ethical, and human-centered design to ensure responsible integration of disruptive technologies.

- Coordinated policy action is required to invest in public infrastructure, teacher capacity, and participatory governance, thereby ensuring that innovation translates into meaningful learning outcomes for all learners.

Policy Context and Problem Definition:

Across Europe, digital transformation in education has accelerated, particularly during and after the COVID-19 pandemic. While XR/VR and AI have opened new opportunities for interactive, personalized, and immersive learning, they also pose complex challenges:

- **Equity gaps**: access to immersive tools remains uneven across regions, with rural and disadvantaged schools at risk of falling further behind.

- **Pedagogical fragmentation**: VR/XR/AI adoption is often project-based and lacks systemic integration into curricula, assessment, and teacher training.

- **Ethical concerns**: algorithmic bias, data privacy, and learner profiling raise unresolved governance issues.

- **Wellbeing and sustainability**: immersive systems may contribute to cognitive overload, digital fatigue, and environmental pressures through energy-intensive infrastructures.

- **Vendor dependency**: reliance on proprietary platforms risks undermining digital sovereignty and institutional autonomy.

The **e-DIPLOMA project**, supported by the *Digital Europe Programme*, engaged over 400 stakeholders—including students, teachers, policymakers, developers, and families—across six European countries. Insights from participatory brainstorming sessions, pilot classroom implementations, and international case analyses feed into this brief. The recommendations align with the **Digital Education Action Plan (2021–2027)** and the **European Education Area**, while also resonating with broader EU policy goals on sustainability, inclusion, and sovereignty.

Key Policy Recommendations:

1. Invest in Public VR/XR/AI Infrastructure.

Support the development of energy-efficient, accessible, and open-source digital ecosystems. Priorities Smart Learning Labs and immersive classrooms that serve all learners, including those in under-resourced areas. Promote the creation of public VR/XR repositories and national cloud infrastructure to reduce dependency on private monopolies.

2. Build Capacity for Ethical and Inclusive Pedagogies.

Develop national teacher training programmes that go beyond technical skills to include ethics, accessibility, and learner-centered design. Mandate co-creation with teachers and students in the development and deployment of tools. Support peer-learning and mentoring to institutionalize competence.

3. Develop Clear Ethical Governance Frameworks.

Establish national guidelines for responsible AI use in education, including transparency in algorithmic decision-making, data privacy, and bias mitigation. Promote institutional data stewardship strategies, and embed ethics into educational technology procurement.

4. Mainstream Wellbeing and Cognitive Load Management.

Introduce national standards for screen time, ergonomics, and cognitive safety in immersive learning. Fund research into psychological impacts of VR/XR/AI in schools and integrate wellbeing indicators into evaluation tools.

5. Ensure Interoperability and Open Standards.

Coordinate European efforts to develop open technical standards for VR/XR/AI content. Support initiatives that allow data portability, platform compatibility, and sustainable digital ecosystems.

6. Advance Equity, Accessibility and Gender-Inclusive Design.

Apply universal design principles in VR/XR/AI development. Provide assistive technologies and inclusive content for learners with disabilities. Promote gender-sensitive approaches to curriculum design and avoid reinforcing stereotypes through AI models.

7. Strengthen Participatory Policymaking.

Institutionalize feedback loops with educators, learners, families, and civil society in policymaking processes. Build frameworks for continuous dialogue across ministries, educational institutions, and industry actors.

8. Link Digital Sovereignty to Educational Autonomy.

Encourage national and regional investment in sovereign digital education platforms. Limit vendor lock-in by incentivizing local VR/XR/AI development and supporting European technological sovereignty.

Supporting Evidence:

This brief draws upon:

- Thematic analysis of **426 proposals** generated during *6-5-3 stakeholder brainstorming sessions* across seven European Union countries.

- Pilot deployments of VR/XR/AI tools (ClassVR, CoSpaces, AI-based feedback systems) in primary and secondary classrooms environment.

- Technical and ergonomic assessments of VR/XR/AI devices, with attention to cognitive load and physical usability.

- Cross-national case studies highlighting diverse implementation pathways.

- Direct feedback from teachers, students, tech experts, community leaders, and families reflecting lived experiences of immersive learning.

Conclusion

For VR/XR/AI integration in education to be equitable, effective, and sustainable, systemic alignment is essential. The evidence from the e-DIPLOMA project shows that integration of innovative technologies in social sphere requires coordinated strategies that link infrastructure, pedagogy, governance, and wellbeing concerns. By embedding ethics, accessibility, and inclusiveness into policy design, European education systems can ensure that disruptive technologies contribute not only to innovation, but also to social justice and democratic resilience.

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