

Research Article

Raphael Zender*, Miriam Mulders, Axel Peter Wiepke, Jonathan Dyrna, Tobias Möhring, Lilly Kaninski, Ulrike Lucke, Markus von der Heyde, Stefan Lindow, Lisa König, Anne Thilloßen and Thomas Köhler

How XR shapes the future of higher education

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Abstract: Immersive technologies are gaining relevance in higher education. While their use has often been limited to isolated pilot projects, the question is becoming more urgent as to how XR can be integrated in a way that is educationally meaningful, technically reliable, and institutionally scalable. This paper aims to develop desirable visions for the future use of XR in university teaching and to derive key design requirements from them. Thus, a two-phase methodological design was employed, consisting of a cross-status group analysis and an interdisciplinary expert workshop. The results include exploratory future scenarios for the years 2035, 2050, and 2075. They outline possible developments ranging from infrastructural anchoring

and global educational networks to individualized learning environments with novel interfaces. Accordingly, intersectional themes such as educational practice, ethics, and infrastructure are systematically addressed, and strategic options for action are identified for higher education institutions and policy makers.

Keywords: immersive technologies; virtual reality; augmented reality; XR; higher education; educational innovation

1 Motivation

Immersive X-Reality (XR) technologies have increasingly found their way into higher education in recent years. In scholarly discourse, however, challenges in researching and conceptualizing these technologies already arise at the level of terminology. To provide conceptual clarity, we follow definitional work on XR terminology¹ and use XR as a placeholder concept that subsumes multiple formats of extensions or complete substitutions of reality through computer simulation, such as Virtual Reality (VR) and Augmented Reality (AR). We nevertheless acknowledge that AR and VR constitute fundamentally different experiences and should not be conflated at the level of learning design or user experience.

Across educational contexts and levels, XR technologies demonstrated particular potential in areas hard to access, such as the development of psychomotor skills² or the visualization of abstract and distant phenomena.³ From a technology adoption perspective, divergent but complementary trajectories can be observed within the XR spectrum, as indicated by the Gartner Hype Cycle.¹ VR moved through phases of inflated expectations and subsequent disillusionment and was removed from the cycle in 2018 as it transitioned beyond emerging-technology status. In contrast, AR has continued to reappear in evolving forms, reflecting ongoing

*Corresponding author: **Raphael Zender**, Zeppelin Universität, Am Seemooser Horn 20, 88045 Friedrichshafen, Germany,

E-mail: raphael.zender@zu.de. <https://orcid.org/0000-0001-9866-9455>

Miriam Mulders, Chair of Educational Technology and Instructional Design, University of Duisburg-Essen - Campus Essen, Universitätsstraße 2, 45141 Essen, Germany

Axel Peter Wiepke, Komplexe Multimediale Anwendungsarchitekturen, University of Potsdam, An der Bahn 2, 14476 Potsdam, Brandenburg, Germany. <https://orcid.org/0000-0002-0555-4040>

Jonathan Dyrna, Center for Interdisciplinary Digital Sciences, CODIP, TU Dresden, Strehleener Straße 22/24, 01062 Dresden, Germany. <https://orcid.org/0000-0002-3718-0645>

Tobias Möhring, Computer Science, RWTH, Templergarten 55, 52056 Aachen, Germany

Lilly Kaninski, Chair of Educational Technology and Instructional Design, University of Duisburg-Essen - Campus Essen, Essen, Germany

Ulrike Lucke, Institute of Computer Science, University of Potsdam, An der Bahn 2, 14476 Potsdam, Germany. <https://orcid.org/0000-0003-4049-8088>

Markus von der Heyde, vdH-IT, Weimar, Germany

Stefan Lindow, Universität Potsdam, Potsdam, BB, Germany

Lisa König, Centre for Didactic Computer Game Research, University of Education Freiburg, Kunzenweg 21, 79117 Freiburg, BW, Germany

Anne Thilloßen, Lab e-teaching-Transfer, Leibniz-Institut für Wissensmedien, Schleichstr. 6, 72076 Tübingen, BW, Germany

Thomas Köhler, Chair Educational Technology, TU Dresden, Dresden, Germany

¹ <https://www.gartner.com/en/research/methodologies/gartner-hype-cycle>.

innovation dynamics.⁴ At the same time, XR technologies are not only commonly discussed, researched and tested^{5,6} but also increasingly implemented in practice, with productive use partly established in domains such as industry⁷ and healthcare.⁸ In higher education, in contrast, adoption is still mainly driven by motivated instructors or funding programs and therefore remains predominantly confined to project-based implementations.^{7,9} These approaches have proven effective and, in some cases, are being gradually scaled or address concrete challenges in academic practice. From an institutional perspective, this raises questions about how XR technologies can be sustainably integrated and developed beyond current implementation efforts.

In this regard, current frameworks and studies provide valuable insights into the conditions, challenges, and design dimensions of XR adoption in higher education but primarily focus on explaining current practices and facilitating present-day implementation. Less attention has been paid to systematically and methodologically rigorous explorations of how immersive technologies might evolve and become embedded in higher education in the long term, particularly beyond rather short-term adoption cycles or isolated innovation initiatives. In a post-hype context, such future-oriented perspectives are essential to move beyond reactive implementation toward proactive and strategic development. Developing shared, interdisciplinary visions can help anticipate plausible development trajectories, surface underlying assumptions, and identify design requirements that are not yet fully visible in current practice. Against this background, the present paper builds on these considerations to explore future-oriented perspectives on XR in higher education. It addresses the following guiding question:

Which desirable yet realistic visions for the use of immersive technologies in higher education can be developed from interdisciplinary perspectives, and what educational, technological, and societal design requirements follow from them?

The structure of the paper is as follows: First, we provide a theoretical outline and brief related work to position our contribution and introduce the analytical lenses used throughout the paper. This is followed by a description of our methodological approach and the presentation of the developed future scenarios for the years 2035, 2050, and 2075. Central intersectional themes, challenges, and tensions are discussed afterwards. The paper concludes with a summary of the key findings and an outlook on future research perspectives in immersive higher education.

2 Theoretical outline and related work

From a technological perspective, XR is commonly associated with three core technical characteristics: immersion, agency, and representational fidelity. Among these characteristics, immersion is most widely recognized in discussions of XR technologies, as it represents the central dimension along which XR is distinguished from other digital media. At the same time, immersion provides the enabling condition under which other technological affordances, such as agency and representational fidelity, can unfold their relevance in educational contexts. Immersion refers to the objective properties of a system that determines the extent to which sensory information is delivered, and the physical environment is perceptually attenuated, thereby shaping the vividness and inclusiveness of the mediated experience.¹⁰ XR technologies and applications can therefore differ substantially in their degree of immersion, depending on factors such as display technology, field of view, tracking accuracy, latency, and the extent of multi-modal sensory engagement. In educational contexts, these varying degrees of immersion translate into different ways of employing XR, commonly discussed in terms of immersive teaching and immersive learning. Immersive learning refers to individual learning processes supported by immersive media and thus captures the internal, person-specific dimension of educational activity, including learners' subjective experiences as well as resulting learning outcomes.¹¹ Immersive teaching, in contrast, describes the design and enactment of teaching with immersive technologies and focuses on the external, objective dimensions of education, encompassing instructional decisions and learning objectives that can be shaped by teachers and institutions. Translating these distinctions between immersive teaching and immersive learning into sustainable educational practice requires attention to institutional conditions and implementation processes.

For XR technologies to establish themselves as a sustainable component of the future of higher education, institutional embedding is particularly critical. To provide orientation for the practical implementation of XR technologies in higher education institutions, implementation-oriented frameworks are particularly useful. One example of such a framework is the multi-level model of immersive teaching and learning,¹² that distinguishes macro-, meso-, and micro-level conditions shaping educational XR use. The model emphasizes that immersive learning outcomes emerge from

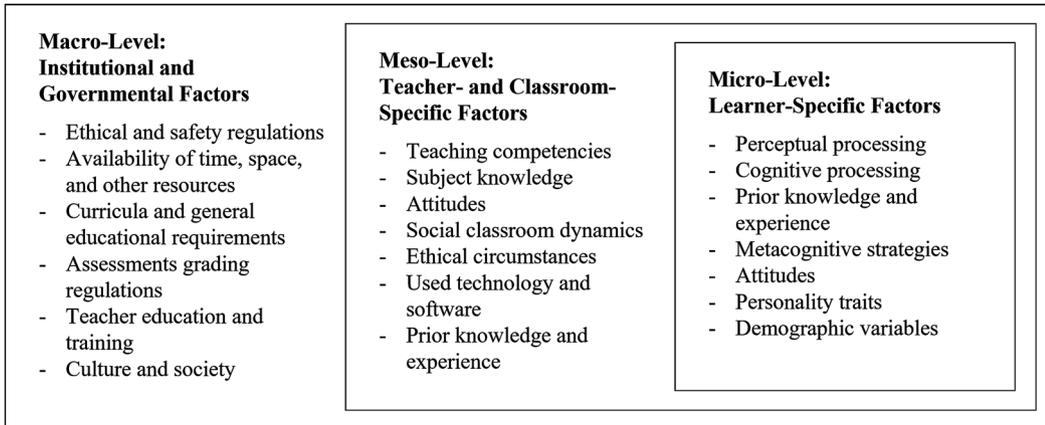


Figure 1: The holistic model for immersive education in the everyday classroom.¹²

the alignment of institutional frameworks and infrastructures (macro), pedagogical and classroom practices (meso), and individual learner processes such as presence, cognition, and motivation (micro). This perspective underscores that XR unfolds its educational potential not as an isolated technology, but through its systematic integration across educational levels. In addition, it outlines exemplary design recommendations, such as decision recommendations for institutional stakeholders to equip learning spaces with flexible, reconfigurable furniture to support immersive learning scenarios at the macro level (see Figure 1).

A second example that complements the previously described framework is the Framework for the Implementation of VR in Formal Education (FIVFE).²¹ Similar to the preceding model, it conceptualizes implementation as a multi-level process that is shaped by specific contextual conditions. Drawing on the change management framework for the sustainable implementation of technology-enhanced learning innovations in higher education,¹³ FIVFE emphasizes the interaction between three sets of framework conditions: The education system with its regulatory structures and processes, the implementing institution with its existing resources, strategies, organizational culture, and support structures, and the individuals involved as stakeholders who bring particular experiences, expectations, and attitudes to the implementation process. Building on these overarching framework conditions, the model further elaborates the concrete design dimensions required for sustainable implementation of XR technologies in formal education by specifying five interrelated areas of action that require purposeful decision-making: instructional design (e.g., the development of pedagogically sound concepts for the use of XR), technology (e.g., the provision of appropriate XR infrastructure), economics (e.g., ensuring a viable cost-benefit ratio), organization (e.g., embedding XR within

and potentially expanding existing institutional structures), and socio-cultural factors (e.g., measures to involve stakeholders in order to foster acceptance and sustained use) (see Figure 2). A key commonality of both models is that, to derive appropriate implementation strategies, (higher) education institutions need to systematically analyze the relevant framework conditions and purposefully define and shape the associated design dimensions.

Against the backdrop of the implementation frameworks outlined above, current practice reveals a range of interrelated framework conditions and design challenges that continue to shape the adoption of XR in higher education. At the level of the implementing institution (macro-level), for instance, acquisition remains difficult for many institutions despite falling costs for head-mounted displays (HMD), particularly in resource-constrained contexts.⁷ Frequent software and hardware updates add financial and logistical burdens. Ongoing hardware and software updates further increase financial and organizational demands, while insufficient interoperability and limited integration into existing infrastructures persist as major barriers – despite being widely recognized as a prerequisite for sustainable and institution-wide implementation. Furthermore, the development of suitable applications for higher education teaching is expensive and complex in terms of both development and design, thus cannot generally be provided by teachers but may require additional expert staff.⁶

From an instructional design and socio-cultural perspective, challenges are particularly evident at the level of involved individuals (meso- and micro-level). Many instructors still lack the pedagogical and technical expertise required to integrate XR meaningfully into teaching practice. Consequently, early implementations may benefit from novelty effects,¹⁵ which tend to diminish with repeated use.

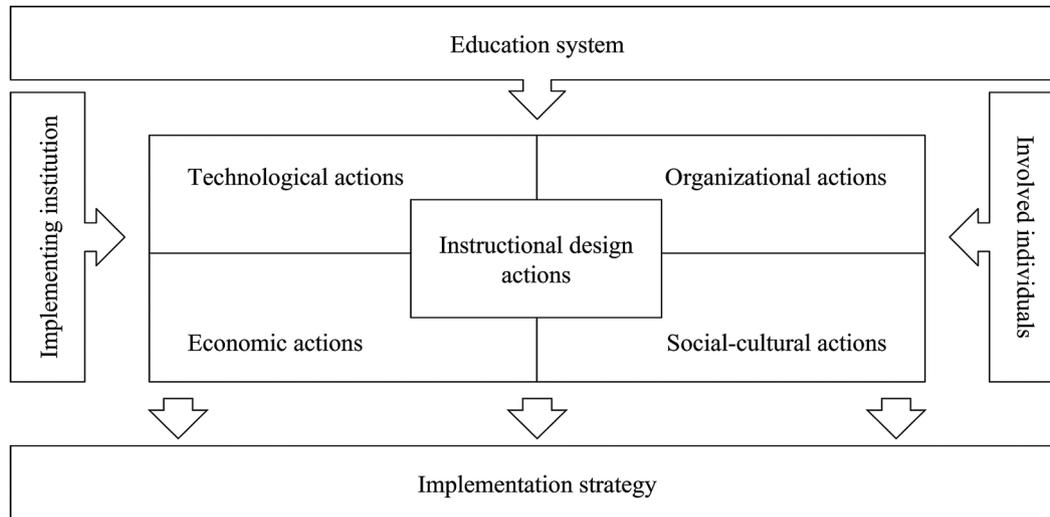


Figure 2: The framework for the implementation of VR in formal education.¹⁴

In line with the design-oriented dimensions emphasized in implementation frameworks, more needs-oriented applications are now emerging that address concrete educational challenges.¹⁶ Supporting this shift requires systematic professional development structures, ideally embedded within higher education pedagogy programs, as well as the use of evidence-based instructional frameworks for immersive learning design, such as CAMIL¹⁷ or more general models like 4C/ID.¹⁸

Further design-related tensions arise at the level of immersive environments themselves (meso-level). While immersive experiences can enhance learning, poorly balanced designs risk cognitive overload, for example through excessive sensory stimulation or overly complex interfaces.¹⁹ Addressing such issues underscores the importance of aligning instructional design decisions with learners' cognitive capacities, as emphasized in instructional implementation dimensions. At the same time, macro-level ethical (i.e., socio-cultural) considerations form an increasingly relevant framework condition. In particular, the collection of biometric and behavior-based data in XR environments raises questions of data protection and responsible data governance, introducing additional organizational and regulatory challenges.^{20,21}

Despite these open questions, XR technologies are becoming increasingly present in teaching practice. As access to technology becomes more commonplace, attention gradually shifts from infrastructure to instructional design. Following the multi-level model of immersive teaching and learning,¹¹ this development can be described as a transition from macro-level conditions to meso-level pedagogical

practices. In parallel, a growing community of students and educators actively engages with XR and acts as a multiplier, extending its use beyond higher education to adjacent educational sectors such as schools. This development signals a broader transition from isolated pilot projects and feasibility studies toward strategic, instructional, and societal considerations concerning the meaningful integration of immersive technologies into university teaching. Building on these developments, it becomes particularly relevant to consider how XR technologies may further evolve and establish themselves in higher education teaching.

Against this background, the aim of this paper is to systematically develop and anticipate possible future visions and development trajectories for the use of immersive technologies in higher education. Rather than focusing solely on technological advancement, as emphasized in early phases of the Gartner Hype Cycle, the paper examines how XR can contribute to learning in a sustainable and pedagogically meaningful manner, drawing on implementation-oriented frameworks to move beyond its function as a mere instructional tool.

At its core, the methodological approach aimed to outline a constructive vision of XR in higher education, focusing on potential and opportunities while acknowledging existing challenges. This perspective was chosen to identify open research questions and inspire discourse in academia, education policy, and practice.

In line with the introduced implementation frameworks, the primary focus is on learning processes (micro-level), pedagogical potential (meso-level), and institutional prerequisites (macro-level) for XR-based educational

offerings in higher education. While aspects of research and university administration are touched upon, they are not the main focus of this analysis. While some arguments may also apply to K–12, our focus is on higher education because of its distinctive coupling of research and teaching (meso-level), advanced infrastructures, and specific governance structures (macro-level).

3 Methodological approach

Developing future visions for immersive technologies in higher education entails uncertainty, as technological, societal, and educational changes follow non-linear, interdependent paths. Against this backdrop, a qualitative, two-part methodological approach was chosen: In the first step (Phase 1), a cross-group analysis of the current technological and educational state of research and development was carried out. In the second step (Phase 2), we conducted an interdisciplinary expert workshop to formulate visions and possible development pathways for the coming decades.

Our qualitative design followed an iterative synthesis across both phases. Inputs from the initial analysis and the expert workshop were captured as short statements, iteratively clustered, and consolidated into the three scenario narratives (2035/2050/2075) as well as the intersectional themes discussed in Section 4. To strengthen transparency and traceability, we provide an anonymized dataset via Zenodo²² with collaboration-board exports and intermediate synthesis artifacts. Materials containing personal data are not published.

3.1 Cross-group, technological and educational analysis

The first step consisted of an initial analysis of the current state of research and development in immersive technologies within the context of higher education. The goal was to identify key potentials, challenges, and open questions that may be relevant for future developments, drawing on academic literature, practical experience, and theoretical models. The analysis was guided by the dimensions of the FIVFE-Framework,¹⁴ which addresses instructional design, organization, technology, economy, and culture (with focus on societal and ethical aspects). Given their close interrelation with organizational and technological considerations in practical implementation contexts, economic aspects were not analyzed as a standalone dimension but were integrated into the analyses of the organizational and technological dimensions. Accordingly, it considered (1)

technological aspects such as hardware development, interoperability, and multimodality, (2) instructional and organizational aspects including meaningful use cases, learning psychology effects, and limitations in higher education, and (3) social and ethical aspects such as data protection, power asymmetries, and potential impacts on learning processes and institutional structures. The data generated during this phase were analyzed using an iterative qualitative approach, combining thematic clustering and interpretive synthesis across the identified framework dimensions.

This phase provided a solid foundation for the workshop. Without it, addressing future development would have been more difficult and less focused. The initial results created a shared reference point for efficient and targeted collaboration.

The analysis brought together faculty and students from educational science and computer science, combining pedagogical and technological expertise to ensure a balanced perspective. Brainstorming, moderated discussions, and clustering addressed technological, educational, and practical questions. The resulting visions were both ambitious and grounded in university practice, serving as input for the next workshop phase with external experts.

Concretely, this Phase 1 synthesis resulted in (1) a consolidated set of clustered themes and areas of tension, (2) an initial set of assumptions and open questions that appeared most relevant for future development trajectories, and (3) preliminary scenario building blocks for the three-time horizons (2035/2050/2075). These outputs served as a basis to design the expert workshop. They informed the guiding prompts and thematic anchors for the group discussions and served as the initial structure of the online collaboration board used for documentation. To strengthen transparency and traceability beyond the manuscript, the intermediate synthesis artifacts from Phase 1 (including clustered themes and mappings used to set up the workshop) are documented in the accompanying dataset.²²

3.2 Expert workshop on vision development

Building on the initial analysis, the second methodological step was an expert workshop focused on developing future visions. To provide structure for this vision-building step, we organized workshop prompts and documentation along the FIVFE dimensions. The aim was to expand, validate, and critically reflect on the preliminary assumptions and collaboratively formulate visions.

The workshop was guided by expert knowledge to anticipate developments. Scenario-based techniques were integrated to foster exploratory and creative development

of future narratives. According to van Notten et al.,²³ the approach was exploratory, participatory, and qualitatively intuitive. It helped visualize and structure future visions and uncover implicit assumptions.

Combining expert knowledge with scenario techniques proved effective: the former ensured systematic consultation, the latter supported creative yet structured vision building. The in-depth discussions enabled insights into disciplinary perspectives and future design requirements.

The workshop brought together 10 scholar and two student experts from disciplines such as computer science, education, media psychology, literature, instructional design, ethics, and policy, reflecting the range of perspectives considered most relevant for addressing the technological, pedagogical, psychological, and societal dimensions of XR in higher education. While the workshop used XR as an umbrella term, participants predominantly referred to VR (HMD-based immersive learning environments) when discussing concrete learning settings and trajectories. This was likely due to the fact that, as outlined earlier with reference to the Gartner Hype Cycle, this technology is more technologically mature and therefore more widely established in higher education than AR, and that several experts have particular expertise in this domain. Table 1 shows an overview of the profiles who participated in the workshop.

The participants combined perspectives from academia and educational practice and were recruited through existing professional networks (including former or current research collaborators) to ensure experience-based

contributions across domains. A dedicated futurology perspective was intended but could not be acquired.

Held online in 2025, the 4-h workshop followed a structured sequence:

1. **Moderated small group discussions** to identify opportunities, risks, and application scenarios for immersive technologies from different perspectives: ethical, organizational, technological and educational.
2. **Timeline-based development of future visions**, in which assumptions and ideas for the years 2035, 2050, and 2075 were systematically collected and organized.
3. **Structured multi-perspective analysis**, reflecting on the results from six different viewpoints (e.g., skeptical, data-driven, emotional or enthusiastic).
4. **Plenary discussion** to synthesize key areas of tension and identify open research questions.

All results were documented on an online collaboration board for transparency, next methodological steps, and subsequent analysis. Based on the documentation, the future scenarios were developed through an iterative process of synthesis, in which recurring themes, assumptions, and tensions were clustered, condensed, and translated into coherent narrative trajectories. As an analytical heuristic to support the interpretation of the scenarios, each scenario was associated with a fictional persona (Alex, a student in higher education), providing a consistent point of reference across scenarios. The methodological mix allowed for an integrated exploration of technological, pedagogical, and societal questions and led to differentiated,

Table 1: Profiles of the workshop participants.

Disciplinary background	Research area	Career level	Role in the workshop
Cognitive Science	Higher education organization, IT architecture	Senior researcher	Expert
Computer Science	Educational technologies/HCI	Prof.	Moderator and expert
Computer Science	Simulation based teaching	Doctoral student	Protocol and expert
Computer Science	Educational technologies	Student/research assistant	Protocol and expert
Computer Science	Educational infrastructures	Prof.	Expert
Educational Sciences	Teaching and learning with VR and AR	Postdoc	Moderator and expert
Educational Sciences	Teaching and learning with virtual reality	Doctoral student	Expert
Educational Sciences	Learning with VR	Student/research assistant	Expert
Educational Sciences	Networking and transfer between research and practice/transfer design with portals	Postdoc group leader	Expert
Educational Sciences/Literature and Media Didactics	Literary and media learning processes	Postdoc	Expert
Social Psychology	Educational technologies	Prof.	Expert
Social Sciences	Infrastructure for science and higher education	Science-management	Expert

practice-oriented, and visionary development trajectories for immersive technologies in higher education.

4 Future visions for XR in higher education

As already outlined, the long-term development of immersive technologies in higher education cannot be predicted with precision, as numerous technological, societal, and educational policy factors interact in non-linear and uncertain ways. Nevertheless, it is both possible and, from a higher education strategy perspective, necessary to formulate plausible and desirable projections. Based on the conducted systematic analysis and interdisciplinary expert workshop, the following visions reflect the subjective assessments of the participants and are not exhaustive but aim to offer orientation and stimulate discussion. Additionally, the visions are illustrated in Figure 3.

4.1 In 10 years: XR is a commodity and established in infrastructure

Over the next 10 years, the consulted experts in higher education expect XR technologies will lose their status as a niche topic in higher education and become increasingly integrated into everyday academic practice. They emphasized that technological progress will contribute to making immersive technologies more affordable, reliable, and

standardized in their application. HMDs will be made available for on-site use and as loan devices through university computing centers, similar to today's laptop pools or computer workstations. According to the participating experts, hardware for audiovisual immersion will be widely and regularly used across many institutions. Haptic and thermal feedback systems are also on the verge of reaching this level of integration. As part of research projects, full-body interfaces for external sensory experiences – including taste and smell – are beginning to emerge.

From the perspective of the consulted experts, XR is evolving from a technological novelty to a meaningful educational tool, supported by the growing integration of XR-compatible learning platforms with learning management systems. They anticipate that hybrid instructional models increasingly apply immersive scenarios for targeted purposes – such as simulation-based assessments or individual support. The experts also highlighted that authoring tools let students create interactive 3D artifacts, including avatars that convey posture and facial expressions, promoting deeper engagement. At an infrastructural level, the experts pointed to developments beyond individual institutions: national and local VR media libraries facilitate content sharing and development, and XR makerspaces serve as hubs for inter- and transdisciplinary collaboration in project-based or preparatory learning formats.^{24,25}

A key technical breakthrough development discussed by the experts concerns the integration of AI into immersive systems. They expect adaptive learning environments to

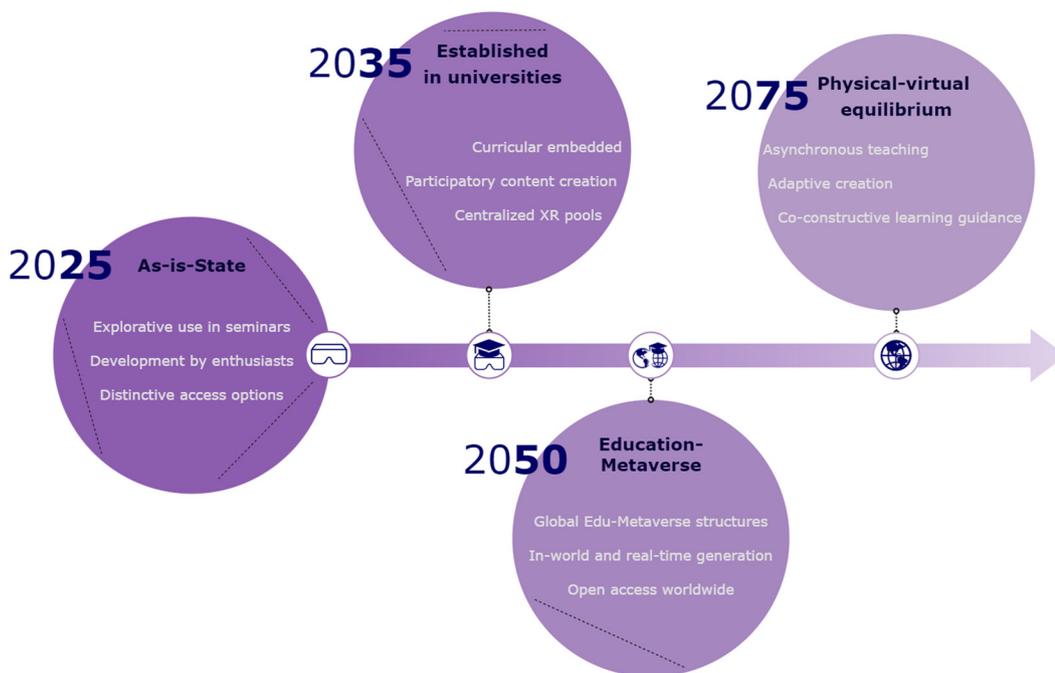


Figure 3: Timeline-based development of future visions for the use of immersive technologies in higher education (2025, 2050, 2075).

increasingly be capable of recognizing students' individual knowledge levels and adjusting content in real time. These adaptations are not limited to cognitive aspects but also draw on data from the affective and psychomotor domains. According to experts, such data is captured via the XR environment – for example, through motion tracking or eye-tracking – which opens up new possibilities for learning analytics,²⁶ but also poses significant challenges in terms of data privacy, ethics, and instructional design.^{2,20}

As a result, the ethical debate continues to gain importance. While technological risks such as cybersickness are significantly reduced through more ergonomic designs and higher-performance hardware, the experts highlighted that concerns regarding privacy, the replicability of real stress scenarios, and accessibility remain central.^{2,27} They further noted that universities are beginning to formulate their own guidelines for immersive teaching formats supported by interdisciplinary ethics committees and focused on fairness in assessment and participation.

Overall, the experts anticipate gradually but steadily, merging of the physical and virtual worlds. Universities continue to exist as “brick-and-mortar” institutions, but increasingly offer hybrid learning spaces that are connected across time and place.²⁸ They particularly emphasized that distance-learning programs benefit from shared XR experiences – for instance, through SocialVR environments that help maintain the social dimension of studying despite the use of hybrid or technology-enhanced learning.²⁹ In the view of the consulted experts, XR will remain selective and purpose-driven but its educational value will be increasingly recognized, enabling low-barrier participation in distributed educational offerings and contributes to greater equity in access.

4.2 In 25 years: XR – enables a global educational infrastructure, the Edu-Metaverse

A quarter-century from now the consulted experts in higher education anticipate that XR will no longer be an optional supplement but an integral part of higher education. From their perspective, immersive technology will be fully embedded in the digital infrastructure of all universities – globally, interoperable, and individually adaptable. What today exists as isolated islands of immersive learning will, in 25 years, have evolved into a connected international network of learning spaces: the *Edu-Metaverse*.

According to the participating experts, standardized interfaces will connect global XR learning environments. Students will attend courses worldwide, explore remote locations, and interact across borders with real-time

translation, cultural cues, and adaptive systems ensuring high-quality virtual social presence. The experts further envisioned this experience will be powered by multimodal interfaces – integrating haptic, thermal, olfactory, gustatory, and even interoceptive feedback (e.g., balance, muscle tension) – via wearables such as XR suits or skin-based displays. In their view, learning will no longer rely on passive reception but will involve comprehensive, interactive participation through fully embodied experiences. Cognitive, affective, and psychomotor dimensions will be addressed simultaneously – for example, in social role-play scenarios or in medical training under emotionally charged conditions.

The experts also expect XR to become the primary interface for work, leisure, and education. Daily schedules will be displayed directly via HMDs by a virtual learning assistant. XR spaces will adapt contextually to the time of day, concentration level, or emotional state. According to the experts, individualized learning environments will filter out real-world distractions and optimize focus and motivation. They further anticipated that authoring tools will not only be intuitive but also available *in-world* and voice-controlled. Instructional concepts will be expressed orally or written and can be automatically translated into immersive learning environments. The creation of learning scenarios will thus become democratized and accessible to all educational stakeholders – regardless of programming skills.

At the same time, the consulted experts emphasized that ethical governance will have matured considerably. Universities will maintain specialized ethics committees for immersive education, working together with international bodies to regularly revise guidelines on data protection, participation, transparency, and health. According to the experts, the integration of biometric data (e.g., movement patterns, heart rate, gaze direction) will enable highly personalized learning environments – while also requiring robust standards for data security, informed consent, and algorithmic fairness.^{20,21}

Across disciplines, the experts anticipate immersive methods to become standard practice – not only in the sciences but also in the humanities and social sciences, where simulation-based environments support reflection, literary reconstructions, or psychology training without reinforcing stereotypes. In their view, communication in XR will transmit nonverbal cues such as body language or microexpressions, increasingly blurring the line between experience and learning.

The experts further expect that the “digital divide” will be largely overcome, as all universities provide free, inclusive access to XR. Networked and scalable infrastructure will ensure availability across user groups.

Following the trajectories comparable to those of the internet,³⁰ the experts envisioned XR content emerging from user-driven, open-source, and community-based platforms. This will allow educational content to be continuously updated – for example, when new historical, cultural, or scientific findings correct outdated models.

Ultimately, the consulted experts described XR as having matured into a medium that not only conveys content but creates educational spaces. For each unit of learning, the university will provide not just knowledge, but also the space, the social constellation, and the individualized learning path in a coherent Edu-Metaverse.

4.3 In 50 years: XR – pervades physical and virtual learning spaces equally

In 50 years, the consulted experts in higher education envision that current hardware limitations will have vanished. As a result, learning will have fully emancipated itself from physical spaces and temporal structures. They furthermore described a future in which the boundary between real and virtual will blur through seamless XR integration and stable brain-computer interfaces (BCIs) that connect perception, communication, and cognition. In this vision, hardware will be invisible, embedded in everyday life and interacting via multimodal channels with sensory and neural processes.

The experts further anticipate that BCIs will enable intuitive control of immersive environments and enable sharing of experiences, emotions, and intentions. They expect learning scenarios to be revisited either in real time or asynchronously. From their perspective, fully virtual Social XR universities will emerge as original institutions, offering personalized learning paths, global participation, and selectable learning settings, including pseudonymized identities.

At the same time, the experts emphasized that physical presence will not disappear entirely in higher education. They noted that in certain contexts classes may still take place in person – for example, in hybrid formats with telepresence robots or in settings where haptic and material experiences remain indispensable. In many cases, however, they expect physical space to become largely obsolete. Field trips to dangerous, historical, or fictional locations will occur entirely within virtual environments – sensory and emotional experiences will be nearly indistinguishable from reality. International communication will be supported by real-time translation in any language.

The experts further envisaged learning support to be provided by intelligent, interactive companions, accessible on demand much like today's podcasts or voice assistants – but embedded within emotional, gestural, and linguistic

contexts. These agents will not merely react but actively co-construct learning processes. Consequently, they expect assessment practices to shift away from discrete, summative formats toward adaptive and formative models. Systems will record long-term interaction data and simulate learners' developmental trajectories over weeks, months, or even years, enabling them to meet both individual and societal needs.

The experts stressed that the societal impact of this transformation will necessitate new legal and ethical frameworks. Behavior, attention, and presence in XR will be regulated. Core concerns – mental integrity, neural data privacy, and algorithmic fairness – will, according to the experts, be monitored by international ethics councils and standard-setting bodies.

Overall, the consulted experts described a future in which higher education is no longer confined to a specific life phase. Lifelong learning will be embedded in daily life, work, and leisure. They emphasized that learning will increasingly shift from information acquisition to experience design. Universities will orchestrate dynamic ecosystems where learners gather, reflect, and share – within a global, pluralistic, interconnected knowledge society.

5 Intersectional themes on the path to the visions

The visions outlined previously highlight XR's transformative potential and, at the same time, call for a systematic engagement with intersectional themes such as educational practice, ethics, and infrastructure, as well as the identification of strategic demands for action for higher education institutions and policy makers. Three themes are of particular importance which are also reflected in the FIVFE: the pedagogical (i.e., instructional) design of immersive learning, social-cultural issues with particular regard to ethics, such as inclusion and data privacy, and the infrastructural (including technological) conditions for sustainable integration. The following sections systematize these areas based primarily on the statements of the workshop experts and are substantiated by relevant academic literature. A detailed view on the workshop and its discussion can be taken on the protocol.²²

5.1 Instructional design and learning processes

The integration of immersive technologies into higher education opens up a wide range of opportunities for

transforming established learning processes. In that light, it becomes clear that XR should not be understood merely as a technical add-on, but as a medium with independent potential for shaping learning spaces, interactions, and processes. This development is likely to create new professional roles and change the ways in which Technology-Enhanced Learning (TEL) and Technology-Enhanced Teaching (TET) is produced and organized. It presents educators as a key group among the individuals involved in the institutional implementation of XR technologies according to the FIVFE, with the challenge of understanding these potentials, identifying gaps in current academic teaching, and integrating XR meaningfully to address cognitive, affective, and psychomotor learning objectives in a targeted manner.

Against this backdrop, and in line with the identified intersectional themes, the pedagogical and instructional design of immersive learning emerges as a central point of departure for examining how XR can meaningfully shape learning processes in higher education. Experiential learning, as described by Kolb in his *Experiential Learning Cycle*,³¹ is increasingly coming into focus. This development stands in contrast to the often cognitively dominated orientation of the academic higher education system and points to a stronger interconnection between theory and real-life contexts. Immersive technologies enable this connection to be shaped in novel ways – for example, through virtual classrooms in which prospective teachers train practical professional skills such as classroom management skills.³² Such scenarios exemplify the increasing integration of practice-oriented teaching and learning formats in academic education. Moreover, XR environments offer the opportunity to concretize abstract learning content. For example, when addressing interdependent global challenges such as advancing the United Nations Sustainable Development Goals,² immersive technologies can transform abstract concepts – like the interplay between social, environmental, and economic factors – into interactive visualizations, simulations, and role-play scenarios that make their complexity more accessible and relatable. This could not only enrich teaching methods but also require curricular adjustments. As such future technologies become increasingly important to society, there is a high demand for well-trained specialists graduating from universities. Immersive learning formats can help promote understanding of complex content and attract more students to these demanding fields of study. As described by Dengel et al.¹¹ at the meso-level, the integration of immersive learning formats hinges on teachers' instructional competencies, their

technological and pedagogical knowledge, and classroom-specific dynamics. XR therefore needs to be embedded in coherent teaching sequences, aligned with curricular goals, and supported by appropriate instructional methods rather than implemented as isolated experiences. This underscores that the growing relevance of immersive technologies entails not only curricular adjustments, but also sustained professional development and collaborative design practices in higher education.

On the way to a broader establishment of XR in higher education, much more publicly accessible and visible best-practice examples are needed – examples that can serve as inspiration and at the same time be directly transferable to different academic cultures and existing teaching formats. Such pioneering projects can function as instructional blueprints, reducing uncertainty in the use of immersive technologies while also providing concrete application impulses for different disciplines. They contribute not only to the professionalization of university teaching, but also support the development of an XR teaching culture that goes beyond individual initiatives.

Three educational lines of development appear to be particularly important for the successful integration of immersive technologies into higher education: First, XR formats must increasingly be intertwined with existing higher education concepts. Second, the professionalization of teaching staff in the handling of immersive scenarios is essential.³³ This includes both technical competencies and understanding of instructional affordances and limitations. Third, evidence-based design principles are needed to reduce extraneous cognitive load.¹⁹

5.2 Ethics and society

With regard to the socio-cultural dimension of the FIVFE, which explicitly emphasizes ethical and societal conditions for the institutional implementation of XR technologies, it is for example important that learner data partly was and will always be around in higher education. The increasing collection of biometric, behavior-based, and context-sensitive data in XR learning environments, as predicted by the consulted experts, requires ethical reflection that goes far beyond classical data protection issues. Immersive technologies not only generate output but also continuously process input in the form of sensitive process data, such as eye tracking, body language, or emotional reactions. This creates the need for interdisciplinary ethics committees that develop university-specific guidelines for data protection, participation, and algorithmic transparency.^{20,21}

At the same time, societal questions of participation come into focus: Are new access barriers being erected, or

² <https://sdgs.un.org/goals>.

are existing ones being dismantled? While XR technologies can make learning spaces more inclusive – for example, through individualized scenarios or the pseudonymization of avatars – they can also introduce new exclusion risks due to visual, sensory, or cognitive demands.²¹ Furthermore, personalization and adaptivity open up the possibility of tracking or profiling, thus posing risks of abusive use of training systems.³⁴ Emotionally charged scenarios must also be discussed, such as realistic simulations of violence, shame, or stress. This raises the question of the extent to which extreme stimuli are legitimate and tolerable in educational contexts,²⁷ or whether they may have negative effects on mental health (e.g., derealization). For this reason, risks associated with XR should be addressed in higher education policy guidelines.³⁵

Overall, ethical frameworks must evolve alongside technological progress. This also includes an international discourse on standards for neural data security and mental integrity – particularly with regard to future interfaces such as BCIs.

5.3 Infrastructure and organization

With reference to the organizational and technological dimensions outlined in the FIVFE, immersive technologies can only achieve a broad and lasting impact if organizational and infrastructural prerequisites are established, while legal frameworks are not addressed here. These include institutionalized XR pools, centrally accessible devices, and support structures – such as makerspaces as physical hubs for XR. Regarding these framework dimensions, XR infrastructure will likely be integrated into university IT strategies – through lending systems, immersive media libraries, or interfaces to learning platforms. This is supported by earlier experiences with mobile devices: initially project-based, they evolved into institutionalized infrastructure and pedagogical use cases, now natural in daily academic life – even missing power outlets are no longer a serious hurdle. A similar trajectory appears similarly realistic for XR technologies if they are institutionally supported and embedded in curricula and governance structures, reflecting the macro-level conditions that shape immersive teaching and learning, such as infrastructural availability, organizational support, and institutional governance.

In this context, the role of the involved individuals, as conceptualized in the FIVFE, becomes particularly salient. Students, in particular, emerge as key actors who not only use XR technologies but actively drive and co-create innovation. They often show high experimental willingness and actively shape usage. This dynamic should be fostered. A

number of today's students, as well as future educators, managers, and coordinators, can act as multipliers. A participatory approach strengthens their commitment.

Additionally, regarding the technological dimension of the FIVFE, interoperability between systems is becoming essential. Open standards are needed to exchange XR content between tools, platforms, universities, and global partners. Vendor lock-in by device manufacturers still hinders this, requiring higher education institutions to speak with one voice. The challenge lies in balancing local flexibility with reuse ambitions. Strong networks are needed to consolidate efforts and avoid duplication.

On the organizational level, long-term viability depends on systematically addressing the needs of all stakeholders – from administration to faculty and students. Authoring tools should be accessible not only to IT professionals, but also to educators and students without technical backgrounds. Broad participation in XR education requires low-threshold tools and services. Ultimately, XR can only become an integral component of higher education if it is sustainably embedded in curricula and governance that addresses educational, technological, organizational, and ethical aspects equally. Early co-design between practice and research during XR development can align technological design with pedagogical needs, sharpen research questions, and increase adoption readiness. Overall, this highlights that the successful implementation and long-term establishment of XR in higher education requires a coordinated interplay between technological, organizational, and instructional design considerations.

6 Discussion

The previously outlined visions and intersectional themes illustrate that the future use of immersive technologies will have far-reaching implications for the strategic orientation and governance of higher education institutions. The outlined desirable yet realistic visions can only be realized if the necessary framework conditions are established within higher education.

6.1 Higher education strategy and education policy

The outlined visions make it clear that XR cannot be regarded as a mere technical add-on. Rather, it must be seen as a strategic issue that profoundly reshapes the structures of higher education and requires adequate course-setting across institutional, pedagogical, and learner-related levels,

as conceptualized in multi-level models of immersive teaching and learning.¹¹

This calls for overcoming project-based logics. Current funding schemes support selective innovation but often lead to isolated solutions without long-term institutional anchoring. While long-term strategies, governance structures, and resource planning can accelerate meaningful integration of XR in higher education, the broad adoption of commodity technologies is often driven more by market dynamics than by institutional initiatives. Consequently, to remain relevant, HEIs need coherent digital strategies – including XR – so that they can shape use, ensure quality, and address risks.

At the same time, education policy must reconsider basic funding mechanisms. The current allocation logic – oriented at enrollment numbers – hinders cooperative and distributed teaching formats. Cross-institutional visions face structural funding limitations. What is needed are models that promote joint developments and reward strategic innovation through shared investment funds, innovation-sensitive performance indicators, or platform infrastructures at the state or federal level.³⁶

Finally, the strategic debate must move beyond technology, focusing on pedagogical quality and the institutional sustainability of XR implementation. Instructors need support in selecting and designing scenarios, while education policy can promote this through targeted funding, training programs, evidence-based frameworks, and the provision and sharing of open educational resources (OER) through dedicated repositories. Moreover, the effects of (foremost physical) learning locations – particularly their didactic design and organizational meaning – need to be studied to better understand the relevance of XR education designs.³⁷ XR thus illustrates the structural changes needed to anchor educational technologies sustainably and responsibly in higher education.

6.2 Ambivalences and areas of tension

The potentials of immersive technologies for higher education are promising – but they are accompanied by tensions that must be critically examined from both societal and educational policy perspectives.

Virtual excursions can contribute to sustainability by reducing CO₂ emissions, yet the energy-intensive nature of XR hardware and computational processes leads to increased resource consumption. In terms of social inclusion, a similarly ambivalent picture emerges: While XR can open up new access pathways to remote settings, high costs and limited usability for certain impairments continue to pose significant barriers.

In the field of intercultural communication, real-time translation and the virtualization of facial expressions and gestures offer new opportunities for mutual understanding. However, the use of avatars may lead to increased anonymity, potentially hindering social closeness. Techniques such as 3D body scanning might address this issue – but simultaneously raise new concerns regarding data privacy and control.

The growing virtualization of learning processes promotes global connectivity but may also displace physical spaces of encounter that have long been essential to social participation, identity formation, and relationship-building. Learning locations themselves risk losing their cultural embeddedness through fully immersive availability – posing challenges to the depth and diversity of academic education.

Further questions concern autonomy, as individual customization and adaptive learning environments face the risk of external control through AI, analytics, and brain-computer interfaces. XR may also help reduce the digital divide if access is open, sustainable, and independent of dominant market actors; otherwise, it risks amplifying existing inequalities. These ambivalences show that shaping immersive educational technologies requires not only technical innovation but also societal, ethical, and political responsibility.

6.3 Reflection: vision or wishful thinking

The future scenarios for the use of immersive technologies in higher education developed in this contribution depict an ambitious vision of academic education in the years to come – with elements that could be seen as utopian or, in some respects, dystopian. Yet, at the intersection of technological feasibility, educational policy constraints, and societal responsibility, the question arises as to their actual realizability – and thus the relationship between vision and wishful thinking.

On the one hand, many of the projected developments are already technologically conceivable: Advances in AI-based personalization, the integration of multimodal interfaces, and early-stage neural interfaces all point to real trends that are likely to intensify over the coming decades. On a societal level, structural drivers can also be identified, such as the growing demand for location-independent, flexible, and personalized learning across the lifespan. XR learning environments could, in this sense, not only transform academic teaching, but also reshape everyday learning – ultimately influencing professional contexts, leisure activities, and patterns of social interaction.

On the other hand, considerable challenges are already apparent today that demand a critical reflection of these visions: Access to XR technologies remains unevenly distributed – both between and within institutions of higher education. At the same time, there is a risk of over-technologization, in which deeper educational goals – such as critical thinking, social belonging, and ethical reflection – might recede into the background in favor of technical possibilities.

7 Conclusions

This contribution developed and critically reflected on future scenarios for the use of immersive technologies in higher education along three time horizons (2035, 2050, and 2075). Drawing on a cross-status analysis and an interdisciplinary expert workshop, the paper synthesized institutional, pedagogical, and learner-related conditions that are likely to shape the long-term integration of XR in academic teaching.

Across all scenarios, a central finding emerges: the educational relevance of XR does not primarily depend on technological sophistication, but on its systematic embedding at multiple levels. At the institutional level, sustainable XR integration requires interoperable infrastructures, governance structures, and funding models that support cooperative and cross-institutional teaching formats. At the pedagogical level, immersive technologies demand coherent instructional design, professional development for instructors, and alignment with curricular goals. At the level of learning processes, XR unfolds its potential particularly where experiential, embodied, and reflective learning activities are purposefully designed.

By consolidating these dimensions, the presented visions move beyond speculative technology narratives and instead outline concrete pathways and tensions for higher education institutions and policymakers. They highlight strategic decision points concerning infrastructure, instructional design, ethics, and access that will determine whether XR becomes a marginal innovation or an integral component of future higher education.

While several of the institutional and organizational dynamics discussed here mirror broader patterns of educational technology adoption, XR adds distinct affordances and constraints – most notably embodied interaction, socio-spatial presence, and sensitive process/biometric data – that warrant dedicated consideration in higher education.

While the scenarios do not claim predictive certainty, they offer a theoretically grounded synthesis that can

inform strategic planning, research agendas, and policy discussions on immersive education.

Future research should build on this work by empirically examining long-term effects of immersive learning environments, refining pedagogical models for XR-based teaching, and further investigating governance and funding structures that enable sustainable and equitable adoption.

Thus, it is clear that such transformations do not arise from technology alone. They require a critical, interdisciplinary discourse on the pedagogical, ethical, and societal implications of immersive education – one that takes both opportunities and limitations seriously, as demonstrated in this contribution. Immersive technologies are not simply “a future that happens” but a future that is to be consciously shaped: responsibly, emancipatorily, and collectively advanced by universities, policymakers, and the scientific community.

8 Transparency statement

We used generative AI tools primarily for language-related support, including proofreading and translation into English. Beyond language, AI was used as an assisting tool during qualitative synthesis (e.g., to support clustering and summarizing workshop contributions) and to support literature scoping (e.g., AI-assisted search such as ChatGPT Deep Research). All AI outputs (text suggestions, clusters/summaries, and literature leads) were critically reviewed by the authors; empirical interpretations and the final synthesis were authored by the research team, who take full responsibility for the manuscript.

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Use of Large Language Models, AI and Machine Learning

Tools: We used generative AI tools (ChatGPT, Gemini) primarily for language-related support, including proofreading and translation into English. Beyond language, AI (ChatGPT, Gemini, NotebookLM) was used as an assisting tool during qualitative synthesis (e.g., to support clustering and summarizing workshop contributions) and to support literature scoping. All AI outputs were critically reviewed by the authors. Empirical interpretations and the final synthesis were authored by the research team, who take full responsibility for the manuscript.

Conflict of interest: The authors state no conflict of interest.

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Data availability: Not applicable. Raw data is not available. However, a comprehensive record of our expert workshop – including collaboration-board exports and intermediate synthesis artifacts – has been published on Zenodo.

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