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Educational Design Guidelines for Teaching with Immersive Technologies—Updating Learning Outcomes of the European Qualification Framework

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Abstract: The advent of immersive technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR), is transforming higher education by providing innovative and interactive learning experiences. This article addresses the imperative of integrating these technologies into higher education systems. The study explores the intersection of immersive technologies and pedagogical strategies, aiming to enhance the European Qualification Framework (EQF) by updating learning outcomes to reflect the competence required in the digital age. Through a comprehensive literature review, case studies, and expert consultations, we propose a set of educational design guidelines tailored for higher education institutions. These guidelines align immersive technology applications with EQF levels and descriptors, focusing on undergraduate and postgraduate education. Our findings highlight the potential of immersive learning to foster critical thinking, creativity, and practical skills, while also addressing challenges such as accessibility and faculty training. By providing actionable insights and recommendations, this paper contributes to the development of a robust framework for incorporating immersive technologies in higher education, ensuring that students are equipped with the necessary skills and knowledge to thrive in a rapidly evolving digital world.

Keywords: instructional design; higher education; immersive technologies; European qualification framework; EQF; learning outcomes; level 6; level 7; level 8

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1. Introduction

The rapid evolution of digital technologies has introduced a new era of educational practices, where traditional teaching methodologies are increasingly being complemented or even replaced by innovative approaches. Among the most promising advancements in this domain are immersive technologies, specifically digital realities [1], such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). These technologies have the potential to revolutionize higher education by offering interactive, engaging, and experiential learning opportunities that extend beyond the capabilities of conventional instructional methods [2].

Immersive technologies in education are not merely supplementary tools; they are reshaping the landscape of learning itself. Under the umbrella of extended reality (XR), which encompasses virtual reality (VR), augmented reality (AR), and mixed reality (MR), these technologies offer transformative educational experiences. VR, for instance, enables students to immerse themselves in simulated environments, allowing for experiential learning that enhances understanding and retention of complex concepts [3]. AR, on the other hand, overlays digital information onto the real world, creating a blended environment where theoretical knowledge can be directly applied to practical scenarios, bridging the gap between classroom learning and real-world application [4]. MR combines elements of both VR and AR, allowing virtual and real-world objects to interact in real-time, further enriching the learning experience by providing a seamless integration of digital and physical environments [5]. Together, these XR technologies are revolutionizing how students engage with content, offering new avenues for creativity, critical thinking, and practical skill development.

The integration of immersive technologies into higher education is particularly significant in the context of the European Qualification Framework (EQF). The EQF aims to standardize qualifications across Europe by defining learning outcomes in terms of knowledge, skills, and competence [6]. As the digital economy continues to expand, there is an urgent need to update these learning outcomes to reflect the competence required in a technology-driven world. Immersive technologies offer a unique opportunity to align educational practices with the demands of the digital age, ensuring that students are not only knowledgeable but also adept at using modern tools and techniques [7].

However, the adoption of immersive technologies in higher education is not without its challenges. Issues such as accessibility, cost, and the need for faculty training present significant barriers to widespread implementation [1,8]. For example, the cost of VR hardware such as headsets and other equipment can be prohibitive for many institutions, especially those in developing countries [2]. Moreover, accessibility remains a concern as immersive content often lacks support for individuals with disabilities. Faculty training also poses a challenge, as many educators need specialized training to effectively integrate these technologies into their teaching practices [2]. Additionally, there is a lack of comprehensive guidelines that align the use of immersive technologies with existing educational frameworks, such as the EQF. Currently, there are no standardized guidelines that specify how immersive technologies should be integrated with EQF learning outcomes. For instance, best practices for determining which immersive experiences are most suitable for each EQF level are lacking, as are protocols for evaluating their effectiveness within different educational contexts. Developing such guidelines could help institutions better utilize these technologies and align them with standardized learning outcomes. This gap in the literature underscores the need for a strategic approach to integrating XR technologies into higher education, one that is informed by pedagogical theory and tailored to the specific needs of educational institutions.

This article aims to address these challenges by exploring the intersection of immersive technologies and pedagogical strategies, with a focus on enhancing the EQF. Specifically, it aims to propose updates to the EQF for levels 6–8, ensuring alignment with the competencies required in the digital age. Through a comprehensive literature review for identifying trends and gaps, case studies for practical insights, and expert consultations for aligning recommendations with educational frameworks, we propose a set of educational design guidelines tailored for higher education institutions. These guidelines are intended to facilitate the effective integration of immersive technologies into undergraduate and postgraduate education (levels 6–8 for higher education), ensuring that learning outcomes are aligned with the competence required in the digital age. The recommendations proposed in this study are primarily aligned with the Greek National Qualifications Framework (NQF), reflecting its current descriptors and learning outcomes. However, the findings also hold broader applicability to the EQF, particularly in their potential to inform updates to EQF levels 6–8 descriptors across European higher educational systems.

To achieve these objectives, the study addresses the following research questions:

- RQ1: How can immersive technologies redefine learning outcomes in higher education?
- RQ2: What are the specific recommendations for integrating these technologies within EQF levels in higher education?

By answering these questions, this article seeks to contribute to the development of a robust framework for incorporating immersive technologies in higher education, ultimately preparing students to thrive in a rapidly evolving digital world.

2. Research Methodology

This study employs a structured and multi-faceted methodology designed to explore the integration of immersive technologies into higher education and their alignment with the European Qualifications Framework (EQF). By combining qualitative approaches and analytical frameworks, the methodology ensures both theoretical rigor and practical relevance. The study begins with a comprehensive review of the relevant literature to establish a strong theoretical foundation and identify trends, gaps, and best practices in the application of immersive technologies (VR, AR, MR) in higher education. Particular attention is given to pedagogical strategies involving immersive technologies and instructional design models applicable to EQF levels 6–8. A literature review enables a synthesis of diverse perspectives, providing critical insights into the potential for immersive technologies to enhance EQF learning outcomes. This foundational step informs the study's theoretical underpinnings and ensures relevance to current educational practices.

Following this, the methodology incorporates illustrative case studies to bridge theoretical concepts with practical applications. Each case study is analyzed for its contribution to skills development, cognitive engagement, and competence-building within levels 6–8, which correspond to higher education. Case studies provide practical evidence of immersive technologies' effectiveness and contextual relevance, supporting the proposed updates to EQF descriptors.

Structured consultations with subject matter experts provide critical feedback and validation for the study's proposals. Experts in instructional design, educational technology, and higher education frameworks, including professionals familiar with the EQF and its application, offered insights to aligning immersive technologies with EQF competency descriptors and addressing implementation challenges such as cost, accessibility, and faculty development. Including expert perspectives ensures that the study's recommendations are practical, scalable, and aligned with current educational priorities.

Finally, to ensure systematic analysis and alignment, the study employs the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional design model, which emphasizes iterative design and evaluation, ensuring that immersive learning experiences remain aligned with both pedagogical objectives and EQF standards. The methodology concludes with a comparative analysis of current and proposed EQF descriptors, highlighting the added value of integrating immersive technologies and providing clear, actionable recommendations for updating EQF descriptors to reflect advancements in educational technology.

3. The EQF, NQF, and Other Competence Frameworks

The European Qualification Framework (EQF) is a tool for comparing the qualifications levels of different countries within Europe [9]. It provides a common reference framework that helps individuals and employers understand and compare qualifications across different education and training systems in the EU. The EQF defines a qualification as "*the formal outcome of an assessment and validation process obtained when a competent body determines that an individual has achieved learning outcomes to given standards*" [9] (p. 7). As the European education and training systems are diverse and reflect national traditions, the EQF has been used as the basis to establish a clear and transparent relationship between the different National Qualification Frameworks (NQFs) and the eight (8) EQF levels, following a learning outcomes approach to provide common descriptions on the expected knowledge, skills, and competence of an individual.

Referring to higher education, the EQF is compatible with the Qualifications Framework for the European Higher Education Area, and its cycle descriptors as the first (undergraduate studies, bachelor's degree), second (graduate studies, master's degree), and third (doctoral studies, Ph.D. degree) cycles of the framework correspond to EQF levels 6, 7, and 8, respectively. Based on the European Higher Education Area, many countries, including Greece, have framed the description of the learning outcomes of each study cycle, aiming to: (a) enhance the transparency of learning and higher education qualifications awarded in the countries participating in the European Higher Education Area, (b) achieve mutual understanding and trust at European and global levels, (c) facilitate the international recognition of periods and qualifications of each country, and (d) facilitate the international mobility of students and graduates for the purpose of continuing their studies or working [10]. Table 1 presents the descriptions of levels 6–8 for higher education, concerning the learning outcomes, specifically knowledge, skills, and competence. In summary, the descriptions for levels 6–8 highlight progressively more advanced requirements for knowledge, skills, and competencies. Level 6 emphasizes advanced knowledge and the ability to manage professional activities, Level 7 focuses on specialized knowledge and strategic problem-solving skills, while Level 8 requires mastery of the most advanced concepts and skills across disciplines.

Table 1. Description [1] of NQF (Greece) learning outcomes for levels 6–8 responding to higher education.

Level	Knowledge	Skills	Competence
6	Has advanced knowledge of a field of work or study, involving critical understanding of theories and principles.	Possesses advanced skills and has the ability to demonstrate the virtuosity and innovation required to solve complex and unpredictable problems in a specialized field of work or study.	Can manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; can assume responsibility for managing the professional development of individuals and groups.
7	Has highly specialized knowledge, some of which is cutting- edge knowledge in a field of work or study and which is the basis for original thinking; has a critical awareness of knowledge issues in a field and at the interface of different fields.	Holds specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields.	Can manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; can take responsibility for contributing to professional knowledge and practices and/or for the performance evaluation of strategy groups.
8	Has knowledge at the most advanced levels of a field of work or study and at the interface with other fields.	Has acquired very advanced and specialized skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation for enlarging and redefining existing knowledge or existing professional practice.	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research.

[1] The descriptions were retrieved from https://proson.eoppep.gr/en/HQFLevels (accessed on 25 November 2024), the current official Hellenic qualifications database.

Despite the comprehensive nature of the EQF in standardizing qualifications across Europe, it is important to highlight that the framework and its corresponding national implementations, such as Greece's NQF, currently lack explicit integration of emerging technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR). These technologies are increasingly recognized as powerful tools in education and professional training, offering new ways to achieve and assess learning outcomes. However, the absence of references to these technologies within the EQF and NQF descriptors suggests a gap in the framework's alignment with modern, technologically enhanced learning environments.

In response to this gap, individual initiatives are emerging that attempt to incorporate immersive technologies into educational frameworks and taxonomies. One such example is the application of Bloom's taxonomy under the XR perspective, as demonstrated by the Open University's OU-MIRAGEXR app [11]. This app introduces evaluative tools for educators that align immersive experiences with Bloom's revised taxonomy, aiming to enhance the assessment of cognitive skills in a more interactive and engaging manner. By leveraging XR, this approach allows educators to evaluate higher-order thinking skills—such as analysis, synthesis, and creation—in a more immersive and practical context, which traditional methods might struggle to assess effectively.

There is a long list of EU Digital Competence Frameworks for teachers, learners and citizens designed to help these target groups assess and develop their digital competence [12]. These frameworks mainly outline the key skills and knowledge needed to use digital technologies effectively, including areas like information management, communication, content creation, safety, and problem-solving. The latest version of the Digital Framework for Citizens (DigComp 2.2, 2022 [13]) is the fourth iteration, and provides new examples of knowledge, skills, and attitudes that help citizens engage confidently, critically, and safely with digital technologies, and new and emerging ones such as systems driven by artificial intelligence (AI).

While these individual cases represent significant progress, they also highlight the fragmented nature of efforts to integrate immersive technologies into broader qualification frameworks like the EQF and NQFs. What is still missing is a cohesive, systematic approach that embeds these technologies into the core structure of qualifications and learning outcomes across Europe. As immersive technologies continue to evolve, their potential to transform educational practices and the competence required in the workforce underscores the need for future revisions of the EQF to incorporate these advancements explicitly. For the EQF and its national counterparts to remain relevant in the digital age, there is a pressing need to update these frameworks to reflect the potential of XR technologies. This would not only enhance the assessment and validation of learning outcomes, but also ensure that learners are equipped with the necessary skills to thrive in increasingly digital and immersive work environments in a rapidly changing technological landscape.

4. Educational Design with Immersive Technologies

The emergence of immersive technologies—virtual reality (VR), augmented reality (AR), and mixed reality (MR)—as a part of extended reality (XR) in education, has necessitated the adaptation of instructional design (ID) models to ensure effective integration in learning environments. These technologies offer unparalleled potential for experiential learning, enabling students to engage deeply with content. However, developing educational frameworks that harness the power of XR while aligning with pedagogical principles remains a challenge.

Beyond the ID models, specific instructional strategies can enhance the effectiveness of immersive technologies in education [1,7,8,14]:

- Experiential Learning: Immersive technologies provide rich environments for experiential learning, where learners engage with content through direct experience. For instance, in VR, students can perform virtual experiments, simulate real-world tasks, or explore historical sites, offering a practical application of theoretical knowledge.
- Problem-Based Learning (PBL): PBL is another strategy that aligns well with immersive technologies, particularly MR and AR. In a PBL setting, students could be given real-world problems to solve, with immersive technologies enabling simulations or augmented environments that provide additional context and tools to support problem-solving. For example, AR can overlay digital data onto physical spaces, enabling learners to access real-time information while working on projects.
- Gamification and Game-Based Learning: Gamification and game-based learning can be seamlessly integrated into immersive environments, providing learners with instant feedback, challenges, and rewards. VR- and AR-based games can make learning more engaging by incorporating competitive elements, narratives, and scenarios where learners must apply their knowledge and skills to progress. For instance, a VR history game can place students in ancient civilizations, where they must navigate social, political, and economic challenges.
- Collaborative Learning: Immersive technologies support collaborative learning by creating shared virtual spaces where learners can interact in real-time. MR environments, for example, allow students to manipulate virtual objects together or engage in

group problem-solving tasks, even if they are in different physical locations. These collaborative immersive experiences help develop teamwork, communication, and critical thinking skills.

- Micro-learning: Immersive technologies could utilize micro-learning as an educational strategy organized at the micro-level, with limited learning objectives and short activities, based on the idea of easy spatial and temporal access to educational content by the learners. Especially in HEI's disciplines like Informatics, Engineering, and Health Studies [15], and VET disciplines such as Electronics, Mechanical Engineering, and Automotive Technology [8], "smart" micro-content could incorporate the use of virtual and augmented reality, as well as Internet of Things (IoT).

One of the core challenges in ID with XR technologies is ensuring that the experiences align with learning outcomes, especially in the context of frameworks like the EQF. Immersive technologies have the potential to address various EQF levels via the following [1,2,8]:

- Enhancing cognitive skills: Immersive environments allow learners to engage in higher-order thinking tasks, such as analysis, synthesis, and evaluation, which are essential for the higher EQF levels.
- Developing practical skills: Immersive simulations can provide hands-on practice in areas such as engineering, healthcare, and the arts, supporting the development of practical skills required at various EQF levels, including levels 6–8 in higher education.
- Promoting soft skills: By placing learners in novel and complex scenarios, immersive technologies encourage communication, collaboration, creativity, and problem-solving, soft skills that are critical for success in the digital age.

Instructional strategies' application and alignment with learning outcomes have been foundational in traditional instructional design models like ADDIE (Analysis, Design, Development, Implementation, and Evaluation) and SAM (Successive Approximation Model) in education for years. However, integrating immersive technologies requires their adaptation to fully harness the capabilities of VR, AR, and MR.

4.1. Educational Design Models and Frameworks Supported with XR Technologies

Since learning and teaching should not be treated separately as they are closely interconnected in education, and the literature refers both to teaching objectives and learning goals leading to learning outcomes [14], in the context of this research we refer both to teaching (instructional) and learning models under the umbrella of educational models. Through a comprehensive literature review including research publications and EU projects reports focusing on educational design with immersive technologies, the following models have been distinguished.

4.1.1. ADDIE, SAM, and SAMR Models

ADDIE (Analysis, Design, Development, Implementation, Evaluation) is a widely used instructional design model that has been adapted early for use with immersive technologies [16,17]. It provides a structured, step-by-step process for educators and/or instructional designers, including the following: (a) Analysis: involves identifying the learning needs and determining the best type of XR technology to use (e.g., VR for highly immersive simulations, AR for enhancing real-world interaction, or MR for combining both); (b) Design: the learning objectives are created and the structure of the immersive experience is outlined—with XR, this could include designing virtual environments, crafting interaction strategies, and ensuring that the experience aligns with the learning objectives; (c) Development: the actual XR content is created, which includes developing virtual environments, programming interactions, ensuring that the software is functional and user-friendly, etc.; (d) Implementation: involves deploying the immersive environment in the educational setting, e.g., VR headsets and applications might be used in classrooms, or AR experiences might be implemented on mobile devices; and (e) Evaluation: after implementation, the effectiveness of the immersive learning environment is assessed, which includes both formative evaluations (ongoing feedback during use) and summative evaluations (assessing learning outcomes after the experience).

The Successive Approximation Model (SAM) is another agile model used in instructional design that emphasizes rapid prototyping and iterative feedback [18,19], making it particularly suited for XR environments. SAM involves short cycles of design, development, and testing, allowing designers to quickly adapt XR content based on user feedback. In immersive environments, SAM is valuable because it allows for real-time modifications of VR or AR applications, ensuring that the final product is refined through ongoing iterations.

The Substitution, Augmentation, Modification, Redefinition (SAMR) model starts by using technology to directly replace an existing tool (Substitution) without any functional change [20]. Next, technology is applied as a substitute, but with functional improvements (Augmentation), which involves adapting current instructional strategies through new, emerging technologies. Following this, technology allows for significant changes in task design (Modification). Finally, it enables the creation of entirely new tasks that were previously impossible (Redefinition). The SAMR model is valuable for guiding educators in enhancing and transforming instructional practices by leveraging technology [21].

4.1.2. Re-Contextualized TPACK Framework

The TPACK (Technological Pedagogical Content Knowledge) framework, when re-contextualized for immersive technologies like VR, AR, and MR, provides a structured approach to integrating technology into instructional design by balancing three core elements: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) [22]. In the context of immersive technologies, this model can be adapted to create more dynamic learning environments, ensuring that technology is meaningfully integrated to support pedagogical goals and subject content. By re-contextualizing the TPACK model [23] for immersive technologies, technological tools like AR and VR could be used to support, rather than overshadow, educational objectives [24]. The balance of pedagogy, technology, and content enables a more seamless integration of immersive experiences into curricula, providing students with new ways to engage with material that also reflects the competencies required in a digital age [24].

4.1.3. XR ABC Framework

The XR ABC (Absorb, Blend, Create) framework, introduced by Shippee and Lubinsky [25], emphasizes how XR technologies can transform learning experiences from passive information absorption to active creation, ensuring that learners can apply and expand their knowledge in immersive environments. The framework is structured around three phases: (1) Absorb—This phase focuses on learners consuming or absorbing information. It involves using XR technologies to present content in an immersive and engaging way, making it easier for learners to understand complex ideas and concepts. (2) Blend—In this phase, learners begin to blend or apply the knowledge they have absorbed by engaging in interactive tasks that integrate both real-world and virtual experiences. This blending can include simulations, practical applications, and collaborative exercises within XR environments. (3) Create—The final phase encourages learners to actively create something new using the knowledge and skills they've gained. This phase leverages XR technology to enable learners to build, design, or innovate in ways that may not be possible in traditional learning environments.

4.1.4. iVR Learning (M-iVR-L) Framework (Especially for VR Environments)

The iVR Learning (M-iVR-L) framework by Mulders et al. [26] is particularly suited for VR skill-based education, such as vocational training, where task simulations play a critical role. In this model VR is used to simulate highly technical tasks, providing students with hands-on experience in a risk-free environment. Continuous, in-environment feedback helps students refine their skills as they practice, while learners can progress at their own pace, mastering complex tasks with multiple attempts, which is critical in practical fields like mechanical engineering [26]. The M-iVR-L puts learning first and immersion second, prioritizing the learning process and applying immersion only as much as necessary for the learning objectives' achievement, avoiding unnecessary interactions in the VR environment. Complex educational tasks are simplified to smaller ones, while guidance during the use of the VR environment is strongly recommended. The calibration of the utilization of IVR throughout various stages of the educational continuum through this framework aims to maximize learning efficacy and enrich the immersive educational experience, thereby advancing the overall quality of the learning process [27].

4.1.5. TESLA Instructional Design Model (Especially for VR Environments but Could Be Extended to XR)

This model synthesizes elements from two instructional design frameworks—ASSURE and TPACK—and incorporates Kirkpatrick's evaluation model (identify the objects of project evaluation: reactions, learning, behavior, and overall project results) to provide a comprehensive approach to training design [27]. Within TESLA, the ASSURE model serves as the foundational design structure, with six sequential stages: Analyze; State standards; Select strategies, technology, and resources; Utilize technology and resources; Require learner participation; and Evaluate and revise. TPACK was integrated in the fourth step of ASSURE to ensure a critical conception of the technology by always foreseeing a close interaction between content, pedagogical, and technological knowledge. Developed by Fragkaki et al. [28], the TESLA model highlights task-based scenarios, where real-world tasks are simulated in VR, promoting critical thinking and problem-solving, and in-scenario assessment tools provide real-time performance feedback. The TESLA model ensures that skills learned in the virtual space transfer to real-world applications, aligning immersive experience with practical needs in education [28]. The integration of diverse instructional strategies within the TESLA model aims to provide a holistic framework that not only facilitates the acquisition of technical skills, but also fosters the development of robust pedagogical foundations [27].

4.1.6. Castronovo et al. Design Model (Especially for VR Environments but Could Be Extended to AR and XR)

The design model of Castronovo et al. [29] is based on the ADDIE instructional design model and focuses on using VR with university students in architectural and construction education. In this approach, students manipulate 3D models and engage in activities that simulate real-world construction tasks, encouraging experiential learning, while the VR environment provides immediate, actionable feedback on design choices and construction strategies, allowing students to refine their skills within the virtual environment.

4.1.7. Instructional Design Model for Immersive Virtual Reality Learning Environments

The instructional model developed by Tacgic and Dalgarno [30] aims to establish an immersive virtual reality learning environment (IVRLE) tailored for training in health education. The researchers present both a systematic design and the development process to elucidate the interrelationships among theory, design, and implementation, while weaving together the principles of learning and teaching towards effectively simulating realistic scenarios that foster deeper learning and engagement [27].

4.1.8. Revealing Project VR-Powered Learning Environments

The Revealing Project [31,32] offers practical, hands-on approaches to integrating VR into classroom settings. The manual aims to enhance the digital skills of both VR-literate and non-literate instructors in higher education, enabling them to seamlessly transition their teaching practices into VRLEs. By offering concrete guidelines and practical examples, this manual helps educators create high-quality learning experiences that leverage the unique affordances of virtual reality. One of the key objectives of this manual is to fill a significant gap in the availability of comprehensive, practical information on VRLEs for HEI instructors.

4.1.9. CAMIL Immersive Learning Model

The Cognitive Affective Model of Immersive Learning (CAMIL) focuses on how immersive environments impact learning through both cognitive and emotional engagement [33]. This model emphasizes that immersive learning experiences (such as VR and AR) have the potential to trigger emotional responses, which in turn influence cognitive processes like memory retention, critical thinking, and problem-solving. In immersive settings, learners are not merely passive recipients but are actively engaged, which helps to solidify their understanding of complex concepts. By leveraging emotional engagement, CAMIL integrates the affective domain of learning (emotions, attitudes, motivation) with cognitive skills to enhance learning outcomes.

4.1.10. TICOL Immersive Learning Model

The Theory of Immersive Collaborative Learning (TICOL) is centered around the use of immersive technologies to foster collaborative learning environments [34]. In virtual settings, learners can engage in team-based problem-solving, project-based activities, and simulations that enhance their ability to work in teams—skills that are highly valued in both academic and professional contexts. TICOL emphasizes the role of social interaction within immersive environments and highlights how collaboration in these virtual spaces promotes active learning, peer engagement, and knowledge sharing.

4.2. Discussion on the Educational Design Models and Frameworks Supported with XR Technologies

The instructional design models ADDIE, SAM, and SAMR, and the re-contextualized TPACK model, are largely focused on supporting educators and instructional designers in structuring effective teaching strategies using immersive technologies. These models provide frameworks for aligning educational goals, content, and pedagogical approaches, considering how technology, in our case XR technology, is integrated to enhance learning processes. ADDIE and SAM offer iterative design methodologies for instructional content, while SAMR helps educators assess the depth of technology integration. The TPACK model, especially in its re-contextualized form, emphasizes the interplay between technological, pedagogical, and content knowledge, helping teachers make informed decisions when implementing digital realities in education.

In contrast, student-centered frameworks such as XR ABC, iVR Learning, and TESLA focus on the learner experience in immersive environments [35]. These models emphasize how learners absorb, blend, and create knowledge in XR environments (as in XR ABC), how VR can enhance skill acquisition (iVR Learning), and the importance of providing immersive environments tailored to specific educational contexts (TESLA).

Building on these, additional models bring further dimensions to the design of immersive learning:

- The model of Castronovo et al. emphasizes using VR for architectural and construction education, providing a tailored approach for industry-specific skills.
- The instructional design model by Tacgin and Dalgarno introduces a comprehensive framework for creating immersive virtual reality learning environments, with an emphasis on cognitive and emotional engagement.
- The Revealing Project's VR-powered instructional design manual provides practical guidelines for higher education, focusing on integrating VR into structured, pedagogically sound lessons.

Finally, both CAMIL and TICOL highlight the importance of affective and collaborative dimensions in learning. CAMIL focuses on how VR can trigger emotional engagement to support cognitive processes, while TICOL explores how immersive environments foster team-based learning and enhance collaboration.

The analysis of instructional design models and their application to immersive virtual reality (IVR) highlights critical challenges in aligning conventional pedagogical frameworks with the unique affordances of immersive technologies. As Radianti et al. [2] pointed out, a significant gap exists in the adoption of explicit learning theories when designing VR content for higher education. Most applications are grounded in experiential learning but rarely integrate comprehensive theories that address the cognitive, affective, and psychomotor domains holistically. For example, while VR applications are widely used to teach procedural knowledge, problem-solving skills, and declarative knowledge, the broader potential of VR—particularly in fostering affective skills—remains underexplored.

Hamilton's review further underscores the need for more rigorous evaluation of VR-based learning outcomes. While immersive VR has shown promise in enhancing cognitive and procedural skills, the transition from virtual to real-world application is inconsistent. Only a few studies included a transfer task, and while the initial results were positive, further research is necessary to confirm whether these skills transfer effectively outside of the virtual environment.

Additionally, as highlighted through this comprehensive literature review, while VR has gained significant attention in educational contexts, it is crucial to expand educational models and frameworks to include other XR technologies, such as AR and MR. AR, which overlays digital information on the physical world, and MR, which blends real and virtual environments, offer distinct advantages in enhancing real-world learning through interactive, context-aware experiences, providing solutions to challenges faced in a VR environment. For example, MR can allow learners to manipulate virtual objects within their physical space, bridging the gap between theoretical learning and practical application.

Moreover, the integration of XR technologies with artificial intelligence (AI) can amplify their educational impact. AI-powered adaptive learning systems, combined with AR and MR, can personalize educational experiences, offering real-time feedback, and adjusting the level of difficulty based on individual learner progress. By creating an ecosystem where immersive technologies and AI work in synergy, we can foster more personalized, engaging, and effective learning experiences. Educational frameworks must evolve to accommodate these advancements, ensuring that they are designed to leverage the unique affordances of each technology for maximum impact.

5. Educational Design and the European Qualification Framework (EQF)

Combining instructional design models such as ADDIE, SAM, SAMR, re-contextualized TPACK, XR ABC, iVR Learning, and TESLA with the European Qualification Framework (EQF), specifically levels 6–8 in higher education, can help create a holistic, competency-driven framework for immersive education. The EQF levels guide the development of qualifications in terms of what learners should know, understand, and be able to do at each stage in higher education. Immersive technologies, paired with instructional design frameworks, can align educational practices with the EQF's focus on competencies:

- ADDIE and SAM offer a structured design process for integrating immersive technologies at various EQF levels. These models guide how educators design curriculum and learning experiences to meet specific learning outcomes (as described by EQF) and ensure that immersive learning activities foster the development of appropriate competencies.
- The SAMR model helps educators think about how immersive technology can progressively transform learning activities, moving from Substitution and Augmentation (lower EQF levels where basic knowledge and skills are acquired) to Modification and Redefinition (higher EQF levels, including 6–8 in higher education, where learners are required to innovate, create, and demonstrate critical thinking).
- TPACK ensures that immersive technologies are used effectively by focusing on the intersection of technology, pedagogy, and content. This ensures that VR/AR/MR experiences are not just novel but are also well-aligned with EQF's requirement that learning outcomes be meaningful and reflect real-world competencies.

Student-centered models such as XR ABC, iVR Learning, and TESLA place more emphasis on how students engage with immersive learning. The XR ABC framework's phases—Absorb, Blend, and Create—correlate with the development of knowledge and skills across EQF levels. For instance, at lower EQF levels, learners absorb fundamental knowledge, progressing to blending skills at mid-levels, and finally to creating new knowledge or products at the highest levels, including 6–8. iVR Learning focuses on vocational training, allowing for skills acquisition in practical, immersive settings, which aligns particularly well with the EQF's focus on skill development. This is particularly relevant for learners at EQF levels 4–6, where applied skills and problem-solving in real-world contexts are critical. The TESLA model promotes adaptive learning environments, where students can move through personalized learning pathways in immersive environments. This adaptability is particularly useful for EQF levels where competencies must reflect specific sectoral needs and allow learners to self-direct and manage complex tasks, including levels 6–8.

Finally, learning models such as CAMIL and TICOL provide insights into how immersive technologies can personalize and enhance learning experiences, ensuring that students develop emotional, social, and cognitive skills that meet EQF competency standards at different levels. CAMIL highlights how immersive environments can foster emotional engagement, a key aspect of competencies such as critical thinking and problem-solving, while TICOL emphasizes collaborative learning through immersive platforms, linking well with EQF descriptors for team-based skills and innovative task management.

Combining these instructional design approaches and learning models with the EQF framework creates a cohesive strategy that ensures immersive learning technologies are pedagogically sound, target specific learning outcomes, and support the development of competencies relevant to the digital age. Such approaches would allow for the design of immersive educational experiences that foster digital-age competencies while ensuring a structured, scalable approach to meeting qualifications and preparing learners for future job markets.

6. Instructional Design Frameworks for XR Technologies Under EQF

The ADDIE model offers sequential structure and clarity, which allows for an organized flow when applying newer models like XR ABC or TESLA. Under the European Qualifications Framework (EQF), which emphasizes clear learning outcomes aligned with professional competencies, a structured model like ADDIE helps ensure that learning is goal-oriented and measurable. For this reason, we decided to use ADDIE as a fundamental instructional design framework to present how the different instructional design models and frameworks discussed in the previous sessions fit within the ADDIE model to design XR-supported educational scenarios under the European Qualifications Framework (EQF). Table 2 describes instructional design frameworks for XR technologies under EQF for each ADDIE phase.

Table 2. Instructional design frameworks for XR technologies under EQF.

ADDIE Phase	ID Frameworks and Models	EQF Integration
Analysis (Defining Learning Outcomes and Needs)	ADDIE: Begin by identifying specific learning outcomes tailored to XR, such as hands-on skill acquisition or problem-solving in immersive scenarios. Use surveys, focus groups, and task analysis to understand learner profiles and institutional constraints. SAM: Perform a rapid assessment of technological readiness and pedagogical objectives to align with learner needs. SAMR: Map current instructional tasks to XR technology possibilities (e.g., redefining a lab experiment in VR). Re-contextualized TPACK: Assess whether AR or VR enhances the content, considering cognitive, practical, or emotional demands of the subject. For instance, AR might overlay real-world surgical anatomy for healthcare students.	- Explicitly align learning objectives with EQF descriptors for knowledge, skills, and autonomy. - Define how immersive experiences (e.g., VR labs, AR simulations) support competencies for EQF levels 6–8, such as critical thinking and advanced technical skills.

Table 2. *Cont.*

ADDIE Phase	ID Frameworks and Models	EQF Integration
Design (Planning the Instructional Experience)	ADDIE: Create immersive scenarios that closely replicate real-world challenges (e.g., an AR-enhanced construction site for engineering students). Use narrative elements to make experiences engaging and meaningful. SAM: Rapidly prototype VR or AR lessons with stakeholder feedback to ensure usability and alignment with learning goals. XR ABC: Structure learning in three phases: Absorb foundational concepts (e.g., theory lessons in VR), Blend through interactive tasks (e.g., simulations or problem-solving), and create final projects using XR tools. TESLA: Introduce team-based collaborative tasks using shared immersive environments to enhance social learning and teamwork. CAMIL and TICOL: Include activities designed to foster emotional engagement (e.g., empathy-building in healthcare) and collaborative problem-solving.	- Ensure that learning designs correspond to EQF requirements for levels 6–8, such as addressing domain-specific knowledge, critical thinking, and innovation. - Ensure designs are measurable and align with EQF descriptors.
Development (Building Learning Materials)	ADDIE: Develop highly immersive VR environments or AR overlays, ensuring accessibility features (e.g., subtitles or adaptive interactions). Use branching scenarios to allow learners to explore multiple pathways and outcomes. SAM: Iterate content development with frequent testing for interactivity, immersion, and learning efficacy. SAMR: Push beyond substitution/augmentation by fully modifying tasks or creating entirely new XR-enabled activities (e.g., interactive archaeology simulations where students excavate in VR). Revealing Project VRLE: Incorporate hands-on design elements based on real-world professional contexts (e.g., a VR-based crime scene analysis for law students).	Materials should target specific EQF-level outcomes, such as practical skill-building (e.g., surgical VR simulators) and cognitive skills (e.g., critical decision-making tasks in AR-enhanced case studies).
Implementation (Delivering the Experience)	ADDIE: Roll out XR technologies with adequate instructor training to ensure smooth adoption. Develop clear instructions for students on using XR tools effectively. XR ABC: Start with individual tasks (e.g., VR tutorials), progress to blended experiences (e.g., AR group projects), and culminate in learner-generated outputs (e.g., designing a VR-based marketing campaign). TESLA and CAMIL: Encourage collaboration and emotional engagement through group challenges and real-time feedback mechanisms. SAMR: Use AR/VR to transform traditional lectures into immersive explorations (e.g., virtual ecosystems for environmental science courses)	Activities should explicitly tie back to EQF's focus on developing advanced skills and autonomy, such as managing complex projects or innovating in unpredictable work contexts.
Evaluation (Assessing the Learning Outcomes)	ADDIE: Use a mix of formative and summative assessments tailored to immersive learning, such as performance analytics in VR environments or peer reviews in collaborative AR tasks. CAMIL and TICOL: Incorporate tools to evaluate both cognitive outcomes (e.g., critical thinking, problem-solving) and affective outcomes (e.g., empathy, collaboration). Revealing Project VRLE: Leverage engagement metrics, such as time-on-task or task completion rates, to evaluate usability and learning retention. Use XR-specific methods like heatmaps to track user focus and interaction patterns.	Ensure that evaluations demonstrate alignment with EQF descriptors for each level, such as assessing mastery of advanced knowledge (Level 7) or leadership in innovative problem-solving (Level 8).

The combination of these models with the EQF provides a holistic and structured way to design immersive educational experiences. By using ADDIE as a basis, we have aligned various educational models and frameworks with the phases of instructional design, ensuring that the learning outcomes are clear, measurable, and relevant to the competency levels defined by the EQF. Each phase of the ADDIE model is enriched by other frameworks like SAM for iterative design, SAMR for tech integration, and XR ABC for student-centered activities, and models like CAMIL and TICOL for ensuring emotional and collaborative learning in XR environments.

7. Updating Learning Outcomes of the European Qualification Framework Under the Perspective of Immersive Technologies

In this unit we integrate immersive technologies at each level of EQF. By doing so, the learning outcomes can be significantly enhanced to reflect the competencies required in the digital age. Incorporating VR, AR, and MR into educational and professional practices not only prepares students to meet the demands of the evolving job market, but also aligns the qualifications with cutting-edge developments in technology. The incorporation of immersive learning adds a dynamic and interactive dimension to knowledge acquisition, skills development, and competence-building, making learning more effective and engaging, and ensuring alignment with the European Qualifications Framework (EQF). Knowledge of XR technologies refers to understanding their principles, capabilities, and potential applications, such as recognizing how AR can visualize structural designs in construction. Skills encompass both the ability to operate XR tools (e.g., using VR for surgical training) and the technical expertise to create XR applications tailored to specific needs, such as designing VR simulations for hazardous scenarios in manufacturing. Finally, XR technologies serve as educational tools, bridging theory and practice to foster professional development, such as using VR to simulate patient care in healthcare or AR for hands-on machinery training in engineering. By differentiating these competencies, educators and trainers can better target learning objectives, ensuring that XR technologies enhance knowledge acquisition, practical application, and professional skill development effectively.

Tables 3–5 display the suggested revised versions of the original descriptions for levels 6, 7, and 8 of the NQF (Greece) learning outcomes for higher education, as outlined in Table 1. While the recommendations in this study directly align with the descriptors and structure of the Greek NQF, they provide a transferable framework that can inform similar updates within the EQF. This alignment underscores the potential for national frameworks like the NQF to serve as a model for broader European-level reforms.

Table 3. Description of initial and suggested revised versions of the NQF (Greece) learning outcomes for level 6 responding to higher education.

Level	Type	Current Description	Suggested Revised Description
6	Knowledge	Has advanced knowledge of a field of work or study, involving critical understanding of theories and principles.	Has advanced knowledge of a field of work or study, involving critical understanding of theories and principles. *Has advanced knowledge of immersive technologies and their applications, with a critical understanding of how these technologies can enhance his/her field of work or study.*
	Skills	Possesses advanced skills and has the ability to demonstrate the virtuosity and innovation required to solve complex and unpredictable problems in a specialized field of work or study.	Possesses advanced skills and has the ability to demonstrate the virtuosity and innovation required to solve complex and unpredictable problems in a specialized field of work or study. *Demonstrates advanced skills in designing and using immersive technologies (such as VR/AR/MR) to solve complex, unpredictable problems.*

Table 3. *Cont.*

Level	Type	Current Description	Suggested Revised Description
	Competence	Can manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; can assume responsibility for managing the professional development of individuals and groups.	Can manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; can assume responsibility for managing the professional development of individuals and groups. *Manages complex XR-enhanced projects, incorporating immersive technologies into professional or technical activities.*

Table 4. Description of initial and suggested revised versions of the NQF (Greece) learning outcomes for level 7 responding to higher education.

Level	Type	Current Description	Suggested Revised Description
7	Knowledge	Has highly specialized knowledge, some of which is cutting- edge knowledge in a field of work or study and which is the basis for original thinking; has a critical awareness of knowledge issues in a field and at the interface of different fields.	Has highly specialized knowledge, some of which is cutting-edge knowledge in a field of work or study and which is the basis for original thinking; has a critical awareness of knowledge issues in a field and at the interface of different fields. *Holds cutting-edge knowledge of immersive technologies and their application in interdisciplinary fields, critically evaluating the potential of VR/AR/MR to advance research, innovation, and user experiences.*
7	Skills	Holds specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields.	Holds specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields. *Uses immersive technologies to develop innovative solutions, integrating immersive experiences into research and professional practice.*
	Competence	Can manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; can take responsibility for contributing to professional knowledge and practices and/or for the performance evaluation of strategy groups.	Can manage and transform work or study contexts that are complex, unpredictable, and require new strategic approaches; can take responsibility for contributing to professional knowledge and practices and/or for the performance evaluation of strategy groups. *Can manage and transform complex work or study environments using immersive technologies.*

Table 5. Description of initial and suggested revised versions of the NQF (Greece) learning outcomes for level 8 responding to higher education.

Level	Type	Current Description	Suggested Revised Description
8	Knowledge	Has knowledge at the most advanced levels of a field of work or study and at the interface with other fields.	Has knowledge at the most advanced levels of a field of work or study and at the interface with other fields. *Holds the most advanced knowledge of immersive technologies, applying them to redefine existing knowledge and practices in interdisciplinary fields.*

Table 5. *Cont.*

Level	Type	Current Description	Suggested Revised Description
	Skills	Has acquired very advanced and specialized skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation for enlarging and redefining existing knowledge or existing professional practice.	Has acquired very advanced and specialized skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation for enlarging and redefining existing knowledge or existing professional practice. *Applies advanced skills in designing, evaluating, and refining immersive environments* (e.g., *VR simulations, AR tools) for critical research and innovation*.
	Competence	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research.	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity, and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research. *Demonstrates authority and leadership in the development and application of immersive technologies for innovation and research.*

8. Conclusions and Future Directions

Immersive learning technologies offer vast potential for enhancing educational outcomes, particularly in terms of procedural and cognitive skill acquisition. However, to realize the full scope of their benefits, instructional designers and educators must move beyond experiential models and integrate a broader range of learning theories and approaches. This includes constructivism, affective learning, and collaborative learning frameworks, which can help bridge the gap between virtual and real-world learning outcomes. By aligning these advancements with the EQF, we can ensure that immersive technologies are not only innovative but also impactful in preparing learners for the challenges of the future.

The variety of instructional design models discussed, including those focused on educators and those centered on the student experience, provide comprehensive tools for modernizing instructional design in immersive learning environments. The EQF's focus on competencies, particularly in critical thinking, problem-solving, and collaborative work, aligns with the objectives of these models. As immersive technologies continue to evolve, future updates to the EQF can integrate descriptors that specifically address the affective, collaborative, and cognitive engagement components emphasized by models like CAMIL and TICOL. Additionally, the practical guidelines provided by frameworks like Revealing and instructional models tailored to specific domains (Castronovo et al., Tacgin and Dalgarno) can further help in refining competency frameworks within the EQF to meet the demands of immersive learning and digital skills.

This article focuses on the critical need to integrate immersive technologies into higher education systems. It examines the intersection of these technologies with pedagogical strategies, aiming to update the European Qualification Framework (EQF) to better reflect the skills required in today's digital age. By conducting a comprehensive literature review, analyzing case studies, and consulting experts, this study proposes educational design guidelines specifically for higher education institutions. These guidelines map immersive technology applications to EQF levels and descriptors, particularly for undergraduate and postgraduate programs. The findings emphasize how immersive learning can promote critical thinking, creativity, and hands-on skills, while also acknowledging challenges such as accessibility and faculty training. This paper offers practical insights and recommendations, contributing to the creation of a strong framework that supports the integration of immersive technologies into higher education, ensuring students are prepared to succeed in a rapidly changing digital environment.

While this study provides valuable insights into the integration of immersive technologies within higher education and their alignment with the EQF, existing limitations should be acknowledged. The study primarily addresses EQF levels 6–8, corresponding to undergraduate, postgraduate, and doctoral education. Although these levels were prioritized due to their direct relevance to advanced education and professional preparation, the findings may have implications for other EQF levels (e.g., levels 4–5, which focus on vocational training). Future research could explore how immersive technologies might similarly enhance competencies across a broader range of qualifications.

The recommendations draw heavily on case studies and expert consultations, which are influenced by the specific contexts of higher education in Europe, particularly Greece. While the insights are designed to be adaptable, their applicability to other regions or educational systems with differing technological readiness or socio-economic conditions may vary. Moreover, the study assumes access to immersive technologies (e.g., VR, AR) and adequate infrastructure. However, the uneven implementation of these technologies due to cost, infrastructure disparities, and digital literacy levels could hinder adoption, particularly in under-resourced institutions or regions.

Immersive technologies and their applications are evolving rapidly, making it challenging to propose static frameworks or guidelines. The recommendations in this study represent a snapshot of current capabilities and trends, which may require frequent updates to remain relevant as technology advances. Finally, while the research methodology provides a strong theoretical foundation, it does not include empirical validation through large-scale testing or pilot implementations. Future research could involve longitudinal studies or experimental designs to evaluate the practical effectiveness of the proposed educational design guidelines.

By acknowledging these limitations, this study provides a foundation for future work to expand on its findings, address gaps, and further refine the integration of immersive technologies within the EQF. Future research should focus on validating and adapting these recommendations to ensure their full alignment with the EQF, considering the diverse contexts and needs across European higher education systems. Looking forward, an important extension of this work lies in the integration of artificial intelligence (AI) within the European Qualification Framework (EQF) and National Qualification Frameworks (NQFs). AI can provide dynamic, adaptive learning experiences that personalize education based on individual learner needs. By incorporating AI-driven technologies into the EQF and NQF, it is possible to enhance the assessment and validation of learning outcomes, making qualifications more relevant to the competencies needed in an increasingly AI-augmented workforce. This integration could lead to a more agile framework capable of updating learning outcomes in real-time, reflecting ongoing technological advancements and the corresponding shifts in required skills and knowledge.

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