XRGREEN.CON: ENHANCING GREEN SKILLS IN THE CONSTRUCTION SECTOR THROUGH EXTENDED REALITY

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Abstract

The Erasmus+ project XRGREEN.CON focuses on integrating extended reality (XR) technologies into vocational education and training (VET) for the construction sector, with an emphasis on promoting circular economy practices and environmental sustainability. By leveraging augmented and virtual reality (AR/VR) gamified simulations, the project aims to provide hands-on, immersive learning experiences for construction professionals, enabling them to better understand and implement green practices within the industry.

Key project activities include:
1) Identifying skills needs related to XR and environmental protection within the construction sector.
2) Developing curriculum for vocational trainers.
3) Creating virtual and augmented reality scenarios for learners focusing on green topics.
4) Promoting the green and digital transition through XR tools in construction education.

The project is innovative in its approach, particularly in addressing the gap in using XR for vocational training in construction sectors from European Qualification Framework (EQF) levels 3 to 5. It distinguishes itself by allowing trainers, without advanced CAD or programming skills, to design and create XR-based educational content focused on waste valorization and circular economy concepts. Additionally, the project emphasizes the integration of environmental protection practices in all training exercises.

This paper will present the results from the Didactic Guidelines work package, focusing on two main objectives:
1) Understanding the EU academic landscape for VET and higher education curricula related to construction (EQF 3-8), and identifying how XR can support circular economy topics.
2) Identifying the skills needs in the labor market through direct stakeholder engagement.
3) Review of research papers that are centred on the use of XR in the construction industry and related educational fields, especially topics of waste management and circular economy.

Through these objectives, the project aims to develop a continuous curriculum for vocational trainers that will incorporate XR and human-centered design methodologies. The results will culminate in a course curriculum for trainers, incorporating the latest XR technologies and methodologies, ensuring sustainability and adaptability for future developments in the sector.

Keywords: Extended reality, construction, education, circular economy, environmental.

1 INTRODUCTION

The construction sector is undergoing a necessary transformation toward sustainability, driven by climate imperatives, policy changes, and technological evolution. However, current vocational education and training (VET) programs across Europe often lag in equipping learners with the green and digital competencies essential for this transition. The Erasmus+ project XRGREEN.CON addresses this gap by integrating Extended Reality (XR)—including Virtual Reality (VR) and Augmented Reality (AR)—into the VET curricula for construction, emphasizing circular economy principles and environmental sustainability.

This paper presents key findings from the Didactic Guidelines work package, focusing on the analysis of existing VET and higher education curricula at EQF levels 3–5 across partner countries (Croatia, Austria, Spain, Finland, and Latvia), the identification of skill gaps, and a desk review of scientific literature addressing the use of XR in sustainable construction education. The goal is to provide the groundwork for a human-centered, XR-enhanced curriculum for VET trainers in the construction sector.

2 METHODOLOGY

The research followed a **multi-step approach**:

- ✓ **Curriculum Analysis**: A comparative review of national educational frameworks and VET programs across partner countries (EQF levels 3–8), with a focus on the presence of digital and green learning outcomes. The goal of this analysis is to compare the analyzes of individual partner countries with each other and with the European Sustainable Development Goals and the European Strategy for Education and Economic Development, and to determine possible common good elements (knowledge and skills), but even more importantly, to identify those skills that are missing and represent an imperative in today's education and training for the labor market. The collective analysis of the curriculum should provide conclusions and recommendations of learning outcomes that should be included in the curriculum for teachers and trainers in VET programs. Not only VET levels (EQF3-5) are addressed, but also EQF levels 6-8 (proper of higher education) are considered for research. It is considered that the learning outcomes that exist at higher levels can be useful for transfer to lower levels because they are a consequence research, scientific and professional work in specific areas.
- ✓ **Gap Identification**: Detection of absent or insufficient learning outcomes related to circular economy, sustainability, and digitalization through qualitative analysis.
- ✓ **Literature Review**: Analysis of 17 peer-reviewed publications from 2016 to 2024, examining the role of XR in construction education, sustainability, and circular economy topics. The sources used to access the literature are the following: IEEE, MDPI, Wiley, SID (Society Information Display), IOPScience.
- ✓ **Stakeholder Input** (forthcoming): E-surveys and focus groups with VET trainers, students, and industry stakeholders to validate identified gaps and needs.

The curriculum and literature data were synthesized to extract key trends and form the basis of a joint, adaptable XR-enhanced curriculum aimed at VET trainers

3 RESULTS

3.1 Desk research of related projects

The 17 scientific papers that were analysed are summarised in the following table, which indicates the technology addressed (Augmented, Virtual or mixed Reality / AR/VR/MR), the topic within the AEC (Architecture, Engineering and Construction) sector and in case it addresses environmental aspects, are also indicated. References to the papers are indicated corresponding section.

Table 1. Table comparing projects and products using XR in the constructions sector

Study/ Paper /project	**Technology used: AR/VR/MR, other**	**Topic within the construction sector**	**Environmental topics addressed**
[1] ecoCampus	AR combined with a touch-based game interface (on a mobile device)	Building redesign, AEC Education	Sustainable design (the context is redesigning renovations on pre-existing facilities with sustainability as

			a goal)
[2] VSES	VR (on mobile device), GUI, 3D modelling, Blender game engine, key frame animation	AEC Education (safety training)	None
[3] ELBigMAC	VR and NUI (Natural user interface)	AEC Education, BIM, Design	None
[4] ELBigMAC	VR and NUI	AEC Education, BIM, Design	None
[5] Virtual Reality for Design and Construction Education Environment	Different modalities of VR (literature review)	AEC Education	None
[6] Mixed Reality Multimedia Learning To Facilitate Learning Outcomes From Project Based Learning	Different modalities of XR (theoretical approach/literature review)	AEC Education	None
[7] Digital Twin and Web-Based Virtual Gaming Technologies for Online Education	Digital Twin, VR, AR, 3D modelling, 360° video (immersion chamber, mobile devices and browser-based VR/AR)	AEC Education (excavation, construction site visits)	None
[8] iVR system	VR (on headset), AR (on mobile devices), Cloud point, 3D modelling, laser scanner.	Quality Assessment, Construction Inspection and Management	The technology aims to reduce the direct environmental impact of traditional construction inspection by making it remote.
[9] VADERs	VR and AR. Multi-user interfaces, spatial audio, 360° video and 3d modelling	AEC Education	None
[10] Comparing 360° Virtual Reality Learning Configurations for Construction Education	VR, 360° photography, eye and head motion tracking	AEC Education (construction site visits)	None
[11] Group-based VR Training	VR, 3D modelling, immersion chamber, multi-user interface, spatial audio, motion tracking	Safety training for highway construction	None
[12] Virtual Reality in Construction	Unity, 3D modelling, VR (on headset)	Design and BIM	None
[13] Virtual and Augmented Reality Infused in AEC Ir 4.0	Different modalities of XR (theoretical approach/literature review)	All, particular focus on BIM	None
[14] Framework for the Use of Extended Reality Modalities in AEC Education	Different modalities of XR (theoretical approach/literature review)	AEC Education	None
[15] SWOT Analysis of Extended Reality in Architecture Engineering	Different modalities of XR (theoretical approach/literature review)	All	None

and Construction Organizations			
[16] Extended Reality (XR) – A Magic Box of Digitalization in Driving Sustainable Development of the Construction Industry: A critical review	Different modalities of XR (theoretical approach/literature review)	All	Sustainable Construction, Sustainable Development goals (in general)
[17] Extended Reality as a Catalyst for Circular Economy Transition in the Built Environment	Different modalities of XR (theoretical approach/literature review)	All	Circular Strategies (regenerate, close, narrow, and slow). Includes recycling, waste management and reduction, efficient planning, etc.

3.2 Analysis of national curricula

The VET panorama of building and construction of Spain, Austria, Latvia, Finland and Croatia was analyzed country by country. Different parameters were taken into account: EQF levels, learning outcomes of digitalization and learning outcomes of environmental sustainability. The joint analysis showed the following:

All education systems of the partner countries have accredited programs at all EQF levels 4-6. Only Spain has developed a significant number of programs at EQF level 2 and 3, Latvia leads in the number of programs at EQF level 5 (25 programs) with a smaller number in Austria (4) and Finland (only one program). In Spain and Croatia, there are no programs at EQF level 5 in the field of Civil Engineering.

Most VET educational programs at EQF level 3-5 are in Spain and Latvia, some in Austria, while the number is insignificant in Croatia, Finland and Latvia. However, in Croatia and Finland there is a significant number of level 6-8 programs, which define learning outcomes in the field of environmental protection, which can be a useful starting point for lower levels because they are the result of comprehensive scientific research.

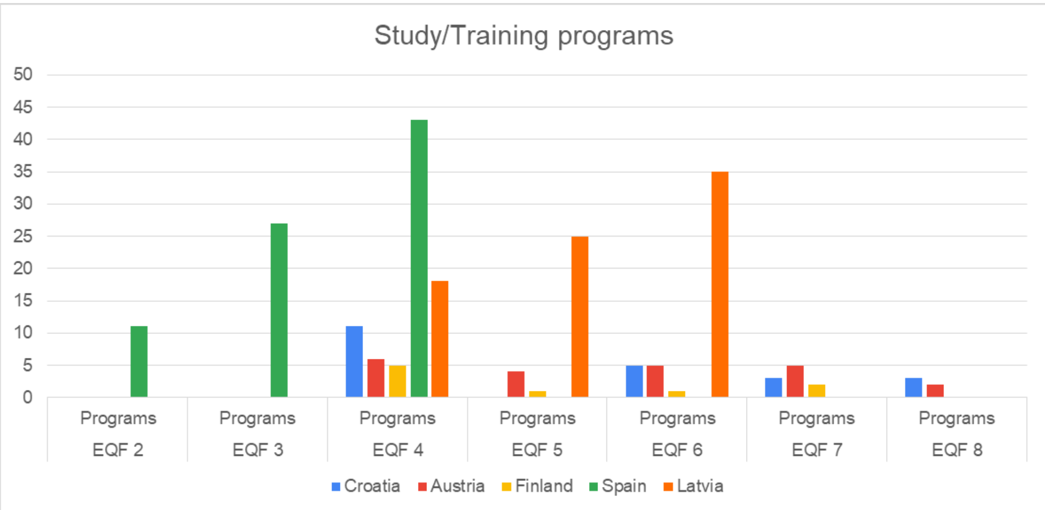

Figure 1. Study/training programmes per country and EQF level.

According to the data shown in the graph below, the most significant number of learning outcomes in the field of digital skills is present in Finland at EQF level 4 and in Croatia at EQF level 7.

Austria and Croatia have these learning outcomes in programs at all EQF levels 4-8, while Spain and Latvia do not have them at all.

Data on learning outcomes in the area of green skills are more varied.

In Spain (the only partner country with programs at EQF level 2 and 3) there are learning outcomes at EQF levels 2-4, mostly at level 2, Finland has by far the largest number of LOs at EQF level 4 and some at 6 and 7, while Croatia and Austria have them at almost all levels.

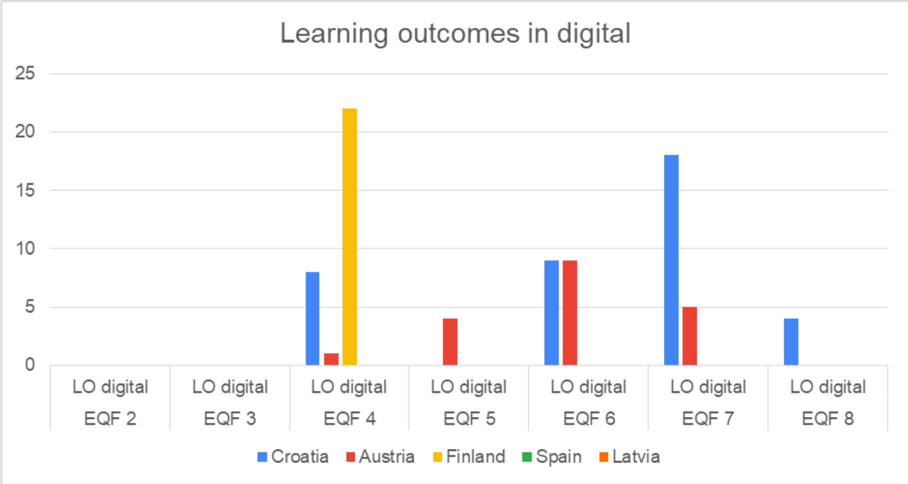

Figure 2. Learning outcomes about digitalization.

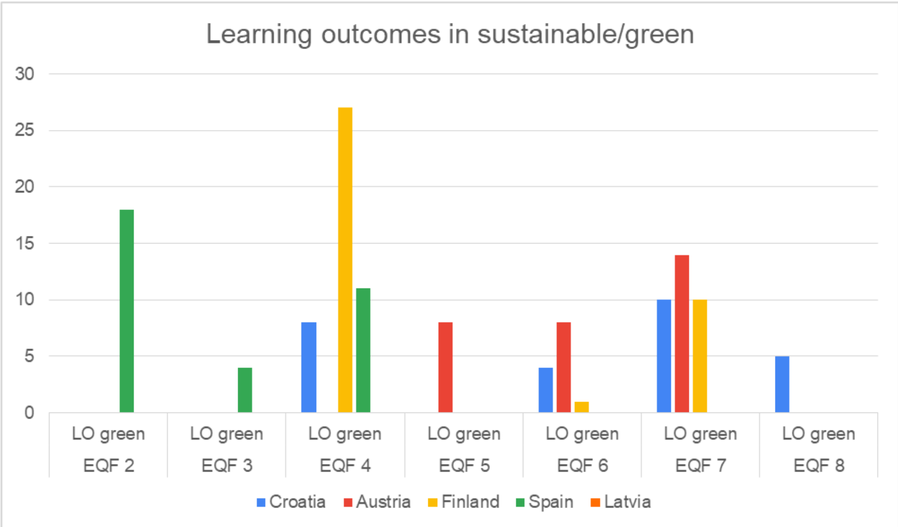

Figure 3. Learning outcomes about sustainability and environmental protection.

If you look at how the analyzed programs are distributed by EQF levels in the pie chart below, you can see that most programs are in EQF levels 4 (39%), twice as many are in EQF levels 6 (22%), about 13% are in EQF levels 5 and 3, and almost insignificantly at other levels.

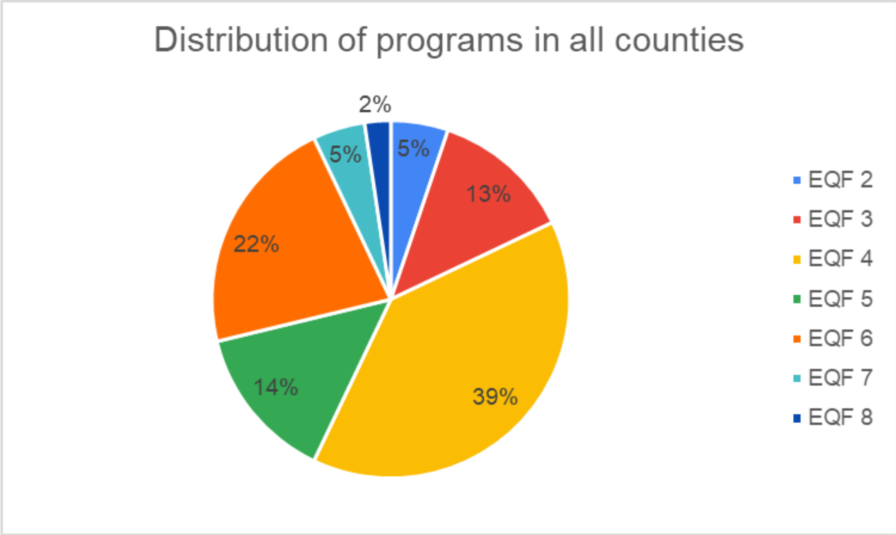

Figure 4. Distribution of programmes per EQF level.

The two pie graphs below show the share of digital and green skills in the programs of individual levels. The largest share of digital skills is in EQF level 4 programs, followed by EQF 7 and EQF 6. There is an evident lack of digital skills at EQF levels 3 and 5.

Green skills are also most represented in EQF level 4 programs, followed by EQF levels 7 and 2. Here, too, the absence of these specific skills is noticeable at EQF levels 3 and 5. One of the main reasons is that the analysis showed a lack of programs at these levels in general in most of the analyzed countries, and where they are developed, they include only professional skills.

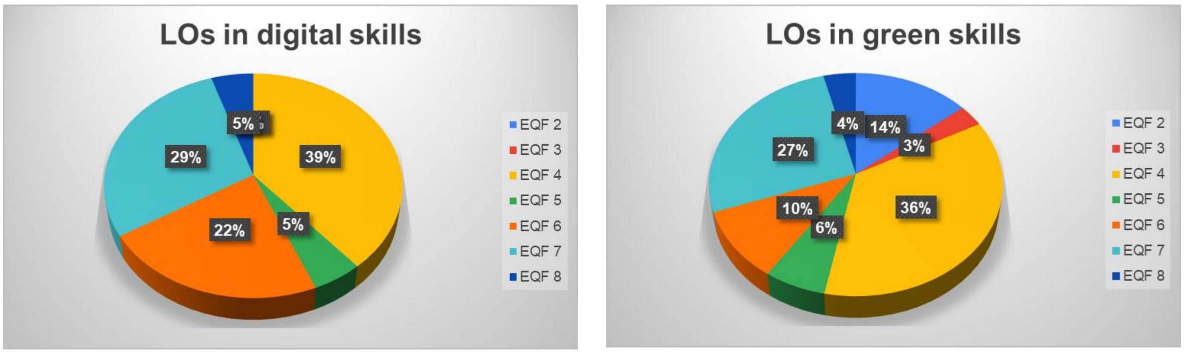

Figure 5. Percentage of learning outcomes related to digital and green skills.

3.3 Cross-section of common elements in the curricula of the partner countries

The most overlap in the number and type of learning outcomes, looking at all partner countries, is in EQF level 4 and 7 programs. Given that the focus of the project is on EQF level 3-5 programs, below is a cross-section of the most significant learning outcomes of EQF level 4 programs and at a higher level that should definitely be included in the new common curriculum with updates based on future online questionnaires and focus groups.

3.3.1 Learning Outcomes in digitalisation

Student will be able to:

- ✓ Use computer aided drawing and design (CAD).
- ✓ Select devices and applications that are appropriate for the purpose.

- ✓ Use appropriate digital devices and applications.
- ✓ Search for processes and shares information of different forms.
- ✓ Assess the reliability of digital content.
- ✓ Use and shares digital content in compliance with copyrights.
- ✓ Use the most common applications for text processing, spreadsheets and presentation graph appropriate digital services and applications in their work tasks.
- ✓ Identify the online communities central to their work.
- ✓ Use platforms and services for cooperative working.
- ✓ Build their professional online identity.
- ✓ Produce and share digital content.

3.3.2 Learning Outcomes in green

Student will be able to:

- ✓ Work without wasting energy, water, and materials.
- ✓ To sort and reuse materials and waste generated in their work.
- ✓ To reduce harmful emissions into the air, water, and soil.
- ✓ To collect, analyze and evaluate data on the impact of the economy, state policy and everyday consumption of citizens on sustainable development.
- ✓ Building ecology.
- ✓ Establish the criteria for the foundation and structure distribution, temporary installations and waste management.
- ✓ Establish the means for protection and risk prevention, along with the adequate environmental corrective measures.
- ✓ Consider factors of climate, environment and energy efficiency, as well as the use of resources (orientation, sunlight, dominant wind, use of eco-friendly materials, use of rainwater, among others).
- ✓ Analyze and develop the information about safety and health, applying established procedures and regulations to elaborate plans for safety and risk prevention as well as for waste management and demolitions.
- ✓ Analyze and use the resources and learning opportunities resulting from scientific and technological evolution on the sector, as well as information and communication technologies, to maintain a spirit of innovation and adapt to new personal and working situations.
- ✓ Understands the importance of biodiversity and recognises the necessity of sustainable use of natural resources nationally and globally.
- ✓ Identifies operating methods of sustainable development in their own life and work.
- ✓ Understands the principles of carbon neutrality and a circular economy.
- ✓ Identifies the energy or material efficiency of a product or a service.
- ✓ Proposes development needs for promoting sustainable development in the future.
- ✓ Operates as an active agent in sustainable development.
- ✓ Assess factors contributing to sustainable development in the workplace or in the vocational field.

3.4 Identification of gaps

Gaps in learning outcomes will be identified after e-survey focus groups result analyses, where different stakeholders, such as companies/industry representatives, teachers and students will give their insight and articulate needs. However, the analysis of learning outcomes of programs at higher EQF levels, EQF 6-7, can identify gaps in learning outcomes that need to be filled, that is, to enrich existing learning outcomes.

3.4.1 Learning Outcomes in digitalisation

Student will be able to:

- Do 3D modelling.
- Use the usual computer tools to perform calculations and simulations for simple systems.
- Be familiar with the BIM concept.

3.4.2 Learning Outcomes in green

Student will be able to:

- Understand the impact of construction on society and the environment.
- Understands recent environmental changes at local and global levels for sustainable development.
- Recognize the importance of social responsibility, including barrier free design for the physical environment.
- Building ecology and sustainable materials.

Beside them, some learning outcomes useful just for teachers could be pointed out from the analysis:

- Use proven tools in accordance with the rules of instructional design.
- Analyze and recognize a given problem in the field of computer vision.
- Choose and prepare design interface of the interactive system.

4 Conclusions and recommendations for new curriculum proposal

Regarding the papers and studies reviewed in this document, the main takeaway is that XR, in different modalities, has been widely used and explored in the context of its application to the AEC industry, particularly in the first two stages of the construction process (design, planning, construction management, etc.). However, when it comes to education and training, their applications are less widespread. Most study cases are tailor-made prototypes, and according to the literature reviews and framework proposals, the implementation of XR technologies in AEC education and construction training is far from established. Main explored areas are safety training, design, construction simulations and virtual site visits, while the main learning goals are engagement and visualisation. Topics of environmental issues are not specifically addressed and, as very recent studies like [16] and [17] evidence, **the application of XR technologies towards particular sustainability goals or circular strategies** is a fresh and new area of research that has only begun to be approached, and its relevance and urgency is emphasised.

The goal of comparing national curricula was to analyze individual partner countries with each other and with the European Sustainable Development Goals and the European Strategy for Education and Economic Development, and to determine possible common good elements (knowledge and skills), but even more importantly, to identify those skills that are missing and represent an imperative in today's education and training for the labor market. The collective analysis of the curriculum provided conclusions and recommendations of learning outcomes that are necessary for students and learners to have and, consequently, **should be included in the** curriculum for teachers and trainers in VET programs.

Looking at individual partner countries, there is a lack of either EQF 3-5 level programs or digital and green knowledge and skills in the field of construction. However, by overlapping the national curricula of all partner countries, a useful cross-section of modern and high-quality knowledge and skills is obtained that is in line with EU goals, climate change and the development of the industry in the construction sector, which can be, together with other tools for data collecting (e-surveys and focus groups), the basis for creating a new curriculum for teachers and recommendations for revising existing or launching new programs in interested educational institutions.

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