D4.3 XR-APPLICATION PILOTING PROGRAMME

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Disclaimer

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Table of Contents

List of abbreviations

DECP	Dissemination, Exploitation and Communication Plan
XR	Extended reality
EdTech	Educational Technologies
SME	Small and medium-sized enterprises
NFT	Non-fungible token
IPR	Intellectual property rights
PDCER	Plan for Dissemination and Exploitation of Results
KPI	Key performance indicator
KER	Key exploitable results
BA	Beacon application
TRL	Technology readiness level
OC	Open call
WP	Work package
FAQ	Frequently Asked Questions
MVP	Minimum Viable Product
PIC	Participant Identification Code
ICT	Information and Communications Technology
ESR	Evaluation Summary Report
FES	Final Evaluation Score
ITES	Technical Excellence
IPES	Pilot Scale and Potential
IBES	Market Readiness and Business Potential

UVP	Unique Value Proposition
Partners' names and acronyms	
CNIT	CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LE TELECOMUNICAZIONI
F6S	F6S NETWORK IRELAND LIMITED
MAG	MAGGIOLI SPA
LS	LIGHT AND SHADOWS
SYN	SYNELIXIS SOLUTIONS SA
SUPSI	SCUOLA UNIVERSITARIA PROFESSIONALE DELLA SVIZZERA ITALIANA
UM	UNIVERSITEIT MAASTRICHT
HOU	HELLENIC OPEN UNIVERSITY
EADTU	VERENIGING VAN EUROPEAN DISTANCE TEACHING UNIVERSITIES
EITM	EIT MANUFACTURING SOUTH SRL

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The XR2Learn Open Call 2 acceleration programme was a comprehensive 12-month initiative designed to foster human-centric XR applications in education and industrial training by utilizing a competitive funnel approach. The process began with the Pilot Specification Phase from months one to three, during which ten sub-projects developed detailed roadmaps and technical-business presentations. Only eight of these projects advanced to the next stage following a weighted evaluation centered on technical excellence and market readiness.

The subsequent Pilot Execution Phase, spanning months four to ten, involved large-scale real-world testing by the sub-projects. This phase featured a critical mid-term review at month six to release initial funding and a final execution validation at month ten to determine which teams would reach the final stage. The programme culminated in the Growth Phase during the last two months of the acceleration programme, where the top three projects transitioned into high-level dissemination and commercialization activities.

Technologically, the sub-projects successfully integrated with the XR2Learn framework by utilizing personalization enablers to create affect-aware learning journeys. The Unique Value Proposition of the sub-projects lies in their alignment with Industry 5.0 values, combining AI-driven affective computing with human-in-the-loop design to deliver scalable and inclusive workforce development tools. This successful validation led to significant international visibility for the winners through physical demonstrations at major exhibitions like the Laval Virtual 2026 conference. Furthermore, the projects contributed reusable 3D assets and instructional courses to the XR2Learn Marketplace and the EIT Manufacturing Academy to foster an open community of practice. By reaching Technology Readiness Levels up to 8, these sub-projects have established a robust foundation for broad commercial expansion across the European manufacturing sector.

1. Introduction

The present document provides a comprehensive overview of the execution and results of the second open call (OC2) of the XR2Learn project. This deliverable is a core output of Work Package 4 (WP4) and specifically addresses Task T4.3 "XR-application piloting". Building upon the foundations and lessons learned from the first open call, OC2 was designed to further enrich the XR2Learn ecosystem by selecting and funding a new cohort of innovative XR applications.

While the first call for proposals successfully established a baseline of high-quality projects, the second call shifted toward a "funnel approach". This strategy was adopted to include a broader range of projects, fostering healthy competition and ensuring that only the most technically robust and commercially viable solutions progressed to the final stages.

New elements were introduced in the OC2 process following the lessons learned from the OC1. A significant update was the introduction of the funnel approach so that more projects would be able to enrich the XR2Learn ecosystem and drive better results.

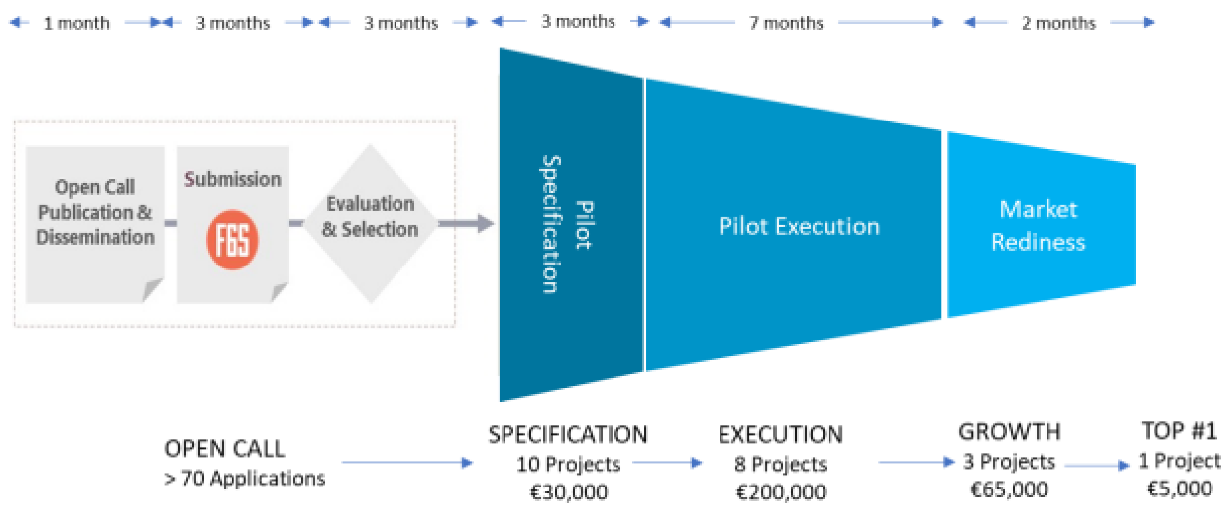

Figure 1: VISUAL PRESENTATION OF XR2LEARN'S OPEN CALL 2 APPROACH

The primary scope of the second open call remained aligned with Industry 5.0 principles, targeting the development of XR tools that enhance human-centric manufacturing, sustainability, and resilient industrial training. The projects selected under this call underwent a structured, three-phase execution programme designed to guide them from initial concept to market readiness. These phases, which are analyzed in detail throughout this report, included:

- **Pilot Specification Phase:** Refining technical architecture and clarifying educational/business parameters.
- **Pilot Execution Phase:** Implementing prototypes, achieving a minimum Technology Readiness Level (TRL) of 6, and ensuring open-source delivery.
- **Growth Phase:** Finalizing business plans, sustainability strategies, and participating in international dissemination events.

Moreover, new requirements were added that reflected XR2Learn's consortium improvement strategy drawn from the OC1:

- Justified utilization of at least one XR2Learn enabler is mandatory (Step 1.1 Eligibility, Annex 2[1])
- Providing an enabler or beacon application is mandatory (Step 1.1 Eligibility, Annex 2)
- Providing content on the XR2Learn platform was added in Criterion 2 Technology.
- Utilization of the XR2Learn educational framework was added in Criterion 2 Technology.
- Details on how the proposed components will be tested and validated and trainees (including gender balance) reached through the piloting of sub-projects.

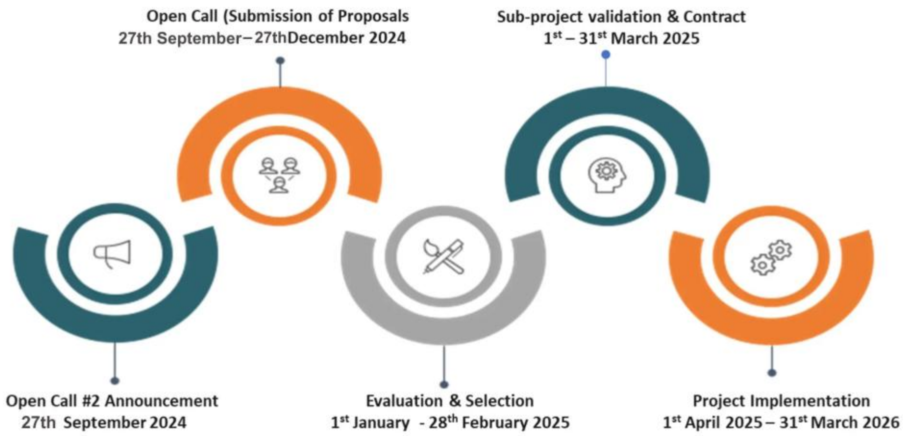

Figure 2: XR2LEARN'S OPEN CALL 2 TIMELINE

This report details the statistics of the applications received, the detailed evaluation process conducted by external experts, the administrative monitoring of the sub-projects, and the final technical outcomes produced. By expanding the ecosystem through OC2, XR2Learn continues to reinforce its commitment to innovation and open collaboration within the European XR landscape and beyond.

Based on the finalized outcomes of the Open Call programme documented in the project reports, the educational impact, course metrics, and trainee reach within the XR2Learn ecosystem can be elaborated through the distinct performance of its sub-projects. More than 800 trainees were reached through the piloting of the OC2 projects. There are 62 3D models elaborated by the OC2 projects that are available on the marketplace. Additionally, they have contributed 7 software applications, 1 library, 9 MOOCs.

Within the XR2Learn ecosystem 15 courses were created, all of them available on the XR2Learn Platform. 80+ trainees are still enrolled for the different courses as of M41.

[1] https://xr2learn.eu/open-call-2/

2. STATISTICS AND EVALUATION PROCESS

2.1. Analysis of the successes and failures of the Open Call 1 projects

This subsection steps on the analysis conducted in D4.4 Open call documentation, reports and analytics and observes the execution of XR2Learn's Open Call 1, which provided key insights used to optimize the design of the second open call. It outlines the successes and failures observed during the OC1 implementation phase and draws the lessons learned for the conduction of the second round. Running from June 29 to September 29, 2023, OC1 aimed to establish and expand the XR2Learn ecosystem with Industry 5.0-aligned educational applications. The call generated significant engagement through webinars and support channels, resulting in 92 total submissions - 76 of which passed eligibility checks. These proposals originated from 20 countries, with a primary focus on the AR/VR and Software sectors.

Surpassing the project's performance target for application volume (KPI 5.3), the success of OC1 demonstrated:

- An effective outreach campaign that successfully engaged target groups.
- High-quality call design supported by clear documentation and guidelines.
- Efficient support mechanisms, including direct communication and a comprehensive FAQ blog, which streamlined the application process.

Despite its success, OC1 presented challenges, including the high level of effort required to support a large applicant pool and manage the extensive evaluation process. The preliminary analysis also revealed limited ecosystem enabler contributions and low trainee engagement for result validation. The analysis of feedback from the seven OC1 winners highlighted the following:

- **General Satisfaction:** Participants gave a mean score of 7 out of 10 for the support provided to marketplace contributors.
- **Primary Goals:** Key motivations for using the platform included visibility (100%) and networking (67%).
- **Content Contributions:** The majority of beneficiaries uploaded software (89%) and 3D models (67%) to the marketplace.

To address these findings and meet specific project targets - such as KPI 2.2 (over 10 enablers used by third parties) and KPI 5.4 (reaching over 1,000 trainees) - the consortium shifted to a "funnel approach" for the second open call. This strategy fosters healthy competition and introduces intermediate control points to improve both quantitative and qualitative outcomes. The rigorous, multi-stage "funnel approach" applied in XR2Learn's OC2 was designed to strategically identify, fund, and advance the most promising XR applications for educational and industrial settings. This competitive framework ensured that resources were concentrated only on projects demonstrating the highest technical excellence, pilot potential, and market readiness.

The structural and operational architecture of the second open call was directly redesigned based on the concrete metrics, beneficiary feedback, and administrative bottlenecks identified during the OC1. The primary successes and failures of OC1, and the corresponding improvements implemented in OC2, are outlined below. Key insights that laid the foundation for the success of OC2 were:

- A shift from Static Funding to a Competitive Funnel Approach - while OC1 successfully generated a high volume of submissions and met its targeted outreach KPIs, it operated as a standard single-stage funding model. This format created severe administrative overload for the consortium due to the massive effort required to support a large applicant pool and evaluate dense proposals simultaneously.
- Mandatory Integration of Technical Enablers - a significant technical shortcoming identified during the preliminary analysis of OC1 was that very few funded projects actually introduced new reusable enablers back into the shared platform. Proposers were not structurally compelled to integrate their workflows with the project's core assets
- Enforcing the Educational Framework and Content Delivery - feedback questionnaires collected from the OC1 beneficiaries indicated that while 100% used the platform to gain visibility and uploaded assets like software (89%) or 3D models (67%), the baseline cohort featured low alignment with systemic educational design rules. To correct this alignment gap, the consortium updated Criterion 2 (Technology) of the external expert evaluation process for OC2.
- Maximizing Trainee Engagement and Large-Scale Validation - the preliminary execution review of OC1 revealed that the initial sub-projects engaged a highly limited number of trainees to validate their real-world deployment. This presented a serious threat to KPI 5.4, which required the open calls to reach a minimum of 1.000 unique trainees through field piloting.

2.2. Statistics on submitted proposals

The second XR2Learn open call was opened for submissions between September and December 2024 on the F6S platform. The call received a total of 148 applications which nears an increase of 60%, compared to the first open call conducted the year before. While the OC was running, an intensive info campaign was conducted to support the potential applicants with the preparation of their proposals. The XR2Learn consortium conducted one [Open Call #2 info webinar] with Q&A sessions, explaining the application process to the broad audience. Parallel to this, a social media campaign took place in order to promote, support and motivate applicants. The Q&A section on the F6S platform was also accessible to answer questions in pre-assigned time, according to the application rules.

Following the application deadline, the eligibility checks process was conducted to filter out any proposals failing to comply with the criteria set forth in the Guide for Applicants (Annex 2)[2] and published on the XR2Learn website. Following the eligibility criteria checks 52 out of the 148 applications were discarded as non-eligible.

[2] https://xr2learn.eu/open-call-2/

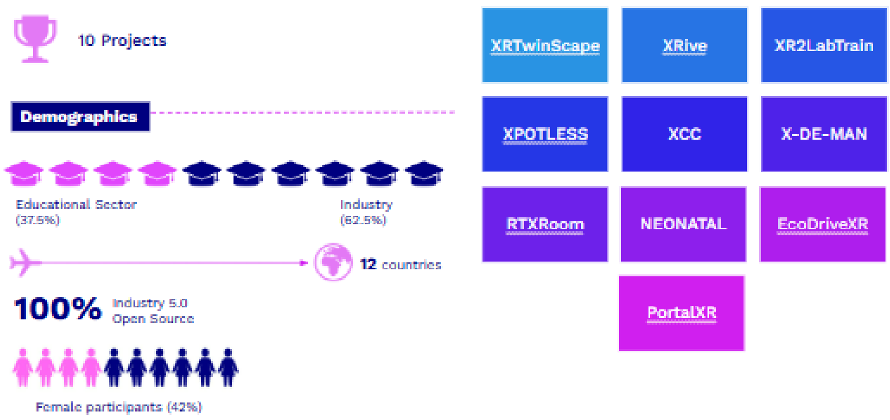

Figure 3: VISUAL REPRESENTATION OF XR2LEARN'S OPEN CALL 2 MAIN STATISTICS

The eligible proposals for this open call originated from legal entities across 20 different European countries, demonstrating a broad geographical reach. Compared to the first open call, there is a noticeable shift toward Eastern and Southern European participants. The 96 eligible proposals arrived from 24 different countries with the top countries being the following:

- Italy (18)
- Greece (15)
- Germany (13)
- Spain (11)
- France (7)

Detailed geographical representation of the OC2 participants is presented below:

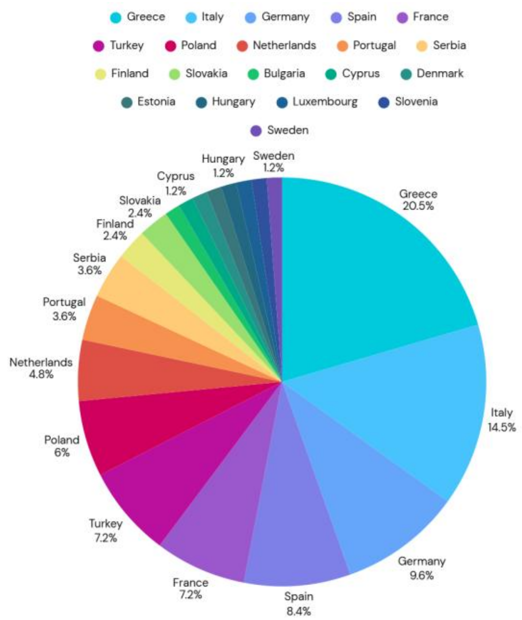

Figure 4: DISTRIBUTION OF APPLICATIONS PER COUNTRY

In terms of the market domain categorization, a new tendency has been outlined in comparison to the OC1. The second open call demonstrated a significant shift in the market focus of applicants compared to the first call. While both calls successfully attracted the project's targeted technical audience, the distribution of expertise evolved as the ecosystem matured. The top markets for OC2 are outlined below:

- AR/VR (42)
- Software (38)
- Education (14)
- Entertainment (12)
- Manufacturing (11)
- AI (10)
- Health/Medical (9)
- Gaming (7)

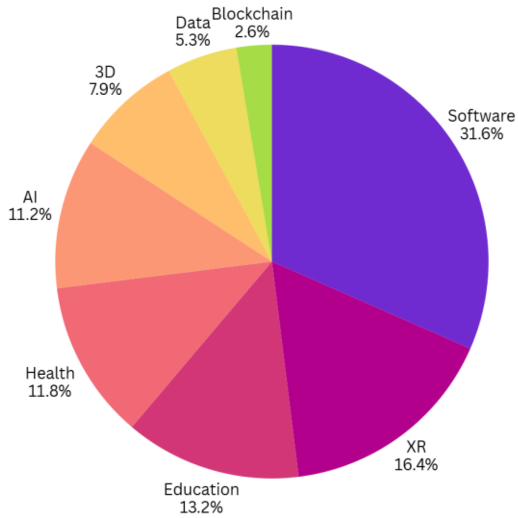

Figure 5: MARKET DOMAINS DISTRIBUTION WITHIN THE OC2

An examination of the proposals reveals that a large majority of the applicants intend to make their outcomes available to the public as open-source material. Because this open-source component was a foundational element of the selection criteria, such a widespread commitment demonstrates that the applicants' goals are closely aligned with the core objectives of the call. This tendency is also visible among the selected sub-projects within OC2 - 8 out of 10 are declaring their results as open source. In addition to the strong open-source orientation, the Open Call also demonstrated encouraging progress in terms of inclusiveness and diversity. Female participants represented approximately 42% of all participants involved in the selected projects, reflecting a relatively balanced gender distribution within a highly technical and XR-oriented innovation environment. Considering the traditionally male-dominated nature of XR technologies, industrial innovation, and software development sectors, this percentage highlights Open Call's success in attracting diverse multidisciplinary teams, including women contributing across technical, educational, healthcare, dissemination, and project management roles. This balanced participation further supports XR2Learn's broader objective of fostering an inclusive and accessible European XR ecosystem.

2.3. Evaluation process

The evaluation of proposals for the second open call followed a rigorous, multi-stage procedure designed to identify high-potential XR applications, reflecting the general aim of the open call to test, pilot, evaluate and validate the user acceptance of new or already developed XR-based applications in real life settings. Building on the experience of the first call, the process was optimized to handle a larger volume of applications (148 in OC2 compared to 92 in OC1) while maintaining high standards of technical and educational excellence in evaluation.

To facilitate the evaluation process and ensure a clear procedure in the selection, the XR2Learn project established a dedicated pool of external experts during the first open call. To evaluate the proposals of OC2, 12 experts were selected from the established pool using the following criteria:

- There should be enough experts so that each expert should evaluate from 8 to 24 proposals (Average 21 proposals)

- No experts will evaluate an application that includes a legal entity located in the same country with the expert
- The experts' gender should be ideally balanced between male and female (7 male and 5 Female)
- The experts' affiliation should be ideally balanced between industry and education (6 EDU/Research and 6 IND/SME)
- Having relevant expertise in AR/VR/XR, AI and Education is considered (Based on the CV if uploaded or google search)
- Having relevant expertise in Open Call Evaluation is considered (Based on the CV if uploaded or previous collaboration)

Out of these experts 7 were male and 5 female and they were located in 10 different countries. The distribution of the organisation types they belonged to is the following:

- Education (4)
- SME (4)
- Research Organisation (2)
- International Organisation (2)

For each proposal, two external evaluators with relevant experience were selected to apply scoring based on a set of evaluation criteria:

- **Concept and innovation:**
    - Innovation, novelty, and feasibility of the proposed XR pilot objectives
    - Design, reliability, feasibility, and quality of the proposed XR pilot.
    - Level of innovation and technological challenges addressed.
    - Applicability to the XR and education scenarios.
    - Number of VR models for educational applications provided through the XR2Learn platform
    - Number of complete educational applications/tools provided through the XR2Learn platform
    - Applicability to Industry 5.0 technologies domain.
- **Technology:**
    - Analysis of the technological and implementation capacity (existing and target TRL and MRL).
    - Quality and feasibility of the workplan (including proposed milestones).
    - Quality of the alignment with the XR2LEARN project.
    - Justified utilization of XR2Learn technology, such as application of existing XR2Learn Enablers.
    - Utilization of the XR2Learn educational framework.
    - Details on how the proposed components will be tested and validated and trainees (including gender balance) reached through the piloting of sub-projects

- **Impact:**
    - Economic and societal impact of the proposed subsystem.
    - Market potential and go to market strategy.
    - European dimension, cross-sector/-border business scalability.
    - Exploitation/business plan and commercialization milestones.
    - Offering the application as open source or not.
- **Applicant/Entity Team:**
    - Capacity to applicant entity/team to perform the task.
    - Knowledge, technological and business expertise.
    - Financial viability/stability and capacity.
    - Commitment of the company and the team.
    - Allocation and justification of requested resources.

Each criterion should get a mark between 1 and 10. The threshold for each criterion will be six (6), while the overall score threshold will be twenty-six (26). It means that if a proposal receives less than 6 in one criterion or less than 26 overall score it is automatically rejected. Each evaluator recorded his/her individual evaluation/opinion of each proposal on an Individual Evaluation Report.

By utilizing the existing pool, the project ensured that the consensus-based evaluation model remained stable. Each proposal in OC2 was assigned to two experts who first evaluated the submission individually before communicating to produce a joint Evaluation Summary Report (ESR). This continuity was particularly valuable for the "funnel approach" adopted in OC2, as the experts were already well-versed in identifying projects that align with Industry 5.0 principles and the project's specific KPIs.

2.4. Selection and contracting

Following the evaluation of proposals for the second open call, a final ranking and selection process was initiated to distribute the €2.100.000 in available EU funding. The selection adhered to a funnel approach, designed to focus consortium resources on the top-performing projects throughout the 12-month program.

2.4.1. Ranking and Selection Procedure

The selection of the final 10 sub-projects followed a structured procedure based on overall scores and specific thematic priorities:

- **Thematic Allocation:** A minimum of 70% of the budget was dedicated to XR applications relevant to Industry 5.0 technologies and skills. The remaining 30% (maximum) was allocated to other educational sectors, such as healthcare, medical, and construction.
- **Ranking Rules:**
    - Proposals were first ranked by their overall score (sum of four criteria: Concept/Innovation, Technology, Impact, and Team).

- In the event of a tie, priority was given sequentially to the scores for Criterion 1 (Innovation), Criterion 2 (Technology), and Criterion 3 (Impact/Market Potential).
- Further ties were broken by prioritizing applications with lower funding requests, those with more female researchers on the team, or those that increased the project's geographical footprint in Europe.

- **Selection Outcome:** Based on these rankings, 10 proposals were selected for funding, while 4 additional proposals were placed on a reserve list.

Quality of the received proposals: The proposals received under the second open call can be considered of high quality. Indicatively, here are some insights and statistics employing the Evaluation Summary Reports of the proposals.

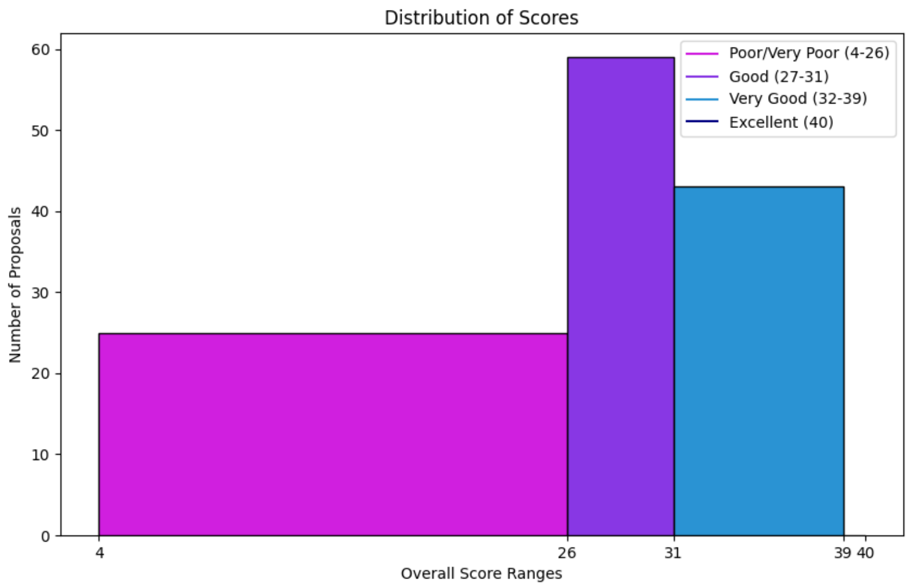

Figure 6: XR2LEARN OC2 CATEGORY SCORES STATISTICS

The above figure displays the distribution of the overall score of the proposals. It is verified that the majority of the proposals received scores above the threshold of acceptance (26). Specifically:

- 76.84% (73 out of the 95 eligible) of the proposals were above 26 as the overall score which is considered as good quality.
- 26.31% (25 out of the 95) of the proposals were above 32, which is considered a very good quality.
- 5.26% (5 out of the 95) of the proposals were above 36, which is considered excellent quality.

The mean values and average for the overall scores and individual criteria are depicted in the table below along with detailed information about the distribution.

Table 1: XR2LEARN OC2 CATEGORY SCORES STATISTICS

	Overall	Concept and Innovation	Technology	Impact	Applicant Entity/Team

Main Score	29	7	7	7	8
Average Score	28,452	7,0625	6,375	7,270	7,791
Fail/Poor/Very Poor	22	10	29	9	8
Good	48	45	46	40	20
Very Good	25	39	20	44	60
Excellent	0	1	0	2	7

2.4.2 Contract Preparation & Signature

Once the final selection was confirmed, the XR2Learn coordinator CNIT began preparing sub-project contracts for the accepted consortia.

After the evaluations the ranking of the proposal followed the procedure described below considering that the available funding is €2.100.000 and that a minimum of 70% of this budget (€1.470.00) should be granted to projects relevant to industry 5.0:

- **Step 1**: The projects dedicated to XR-applications relevant to industry 5.0 technologies will be ranked in a dedicated list following the rules that are described below in this section.
- **Step 2:** From the above list, the top projects in ranked order will be selected having a total requested funding of up to €1.470.000. In case, the total requested funding of the selected projects is below €1.470.000, one additional project will be selected.
- **Step 3:** All remaining projects will be ranked again in a single list following the rules that are described below in this section.
- **Step 4:** From the new list, the top projects in ranked order will be selected so that the total requested funding from all Open Call 2 projects (the ones selected in Step 2 plus the ones selected in this step) to be up to €2.100.000.

Following the procedures described in previous sub-sections, ten projects were selected to be funded. All the proposals received a letter of acceptance or rejection together with an anonymised version of the ESR. The selected projects participants originated from ten different countries. Out of the 17 unique participants in the projects, 10 of them are declared as SMEs. Additional details about the projects are displayed in the following table:

Table 2: List of selected projects in XR2Learn's OC2

Project Acronym	Title	Country of coordinator	Partners

XRTwinScape	XRTwinScape: Advancing Contextualized Learning and Training for Industry 5.0 Through Immersive Virtual Environments	Italy	1. Formamentis SPA 2. Centro Regionale Information Communication 3. Picaresque SRL
XRive	Immersive XR Training Applications for Human-Centric Safety and Innovation in the Automotive Industry	The Netherlands	1. ENEBULA BV 2. AviSense.AI technovlastos P.C. 3. InterMediaKT - Interactive Media KnowledgeTransfer
XR2LabTrain	Your Gateway from Virtual Labs to Real-World Impact	Austria	1. Mindconsole GmbH 2. Profactor GmbH 3. THI Techhouse GmbH
XPOTLESS	XR experience for Training cleaning and disinfection Safety practices in the agrifood sector	Spain	1. ENCLAVE FORMACIÓN S.L.U. 2. ASOCIACIÓN DE INVESTIGACIÓN DE INDUSTRIAS
XCC	XR CROWD CONTROL	France	1. MIMBUS SAS 2. DAHER
X-DE-MAN	eXtended reality platform enabling self-resilient operator in DE-MANufacturing industry	Italy	1. MORE SRL 2. UNIVERSITÀ DEGLI STUDI DI PARMA
RTXRoom	Remote Training XR Room	Greece	1. D-CUBE PRIVATE COMPANY 2. BUILDING SYSTEMS INNOVATION CENTRE IDIOTIKI KEFALAIOUCHIKI ETAIREIA
Portal - XR	Port Operations and Risk Training with Advanced Learning in XR	Romania	1. BYTELEPA SOLUTIONS S.R.L. 2. Embedded Systems Design & Applications University of Peloponnese 3. Thessaloniki Port Authority S.A.
NEONATAL	Simulated Neonatal Resuscitation Training for European Healthcare Workers	Denmark	1. Khora 2. Region Hovedstaden
EcoDrive XR	Immersive Training for Sustainable Electric Vehicle Manufacturing	Slovakia	1. Matsuko s.r.o. 2. Stredná odborná skola Ucnovská 5, Kosice – Saca

3. EXECUTION OF OPEN CALL 2

The execution of the second open call was structured into three distinct phases designed to guide selected projects from pilot specification to market readiness. The programme ran for a total of 12 months, starting from April 1, 2025, to March 31, 2026. The programme utilized a competitive funnel structure to distribute a total budget of €2,100,000. The execution was divided into three progressive phases as shown on the graph.

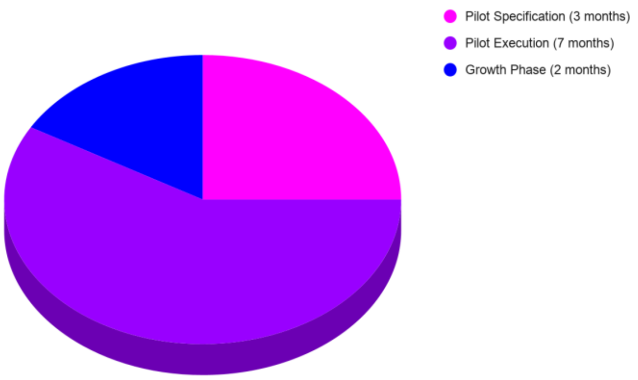

Figure 7: EXECUTION PHASES OF XR2LEARN'S OC2

A visual representation of the timeline for the XR2Learn second open call is the following:

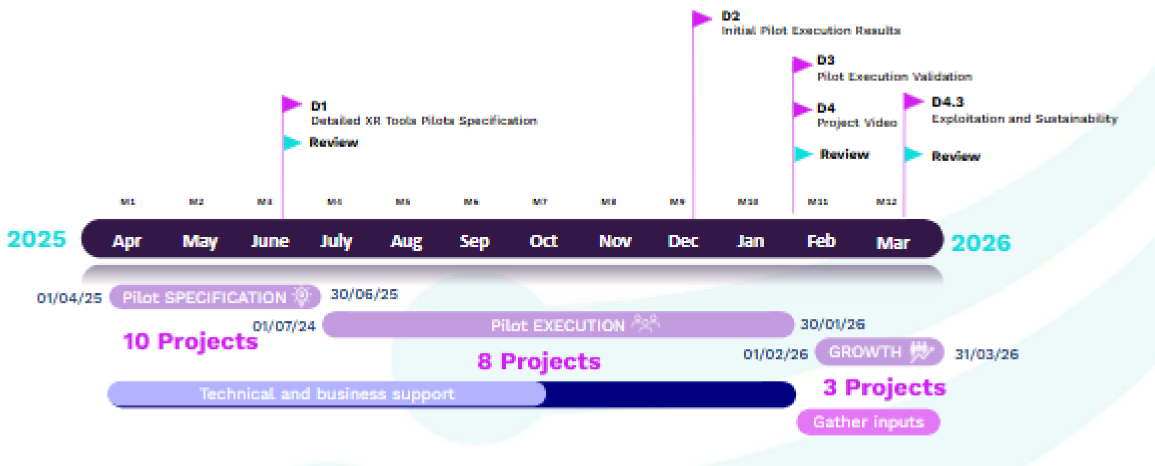

Figure 8: VISUAL PRESENTATION OF XR2LEARN'S OC2 EXECUTION

3.1. Pilot Specification Phase

The Pilot Specification Phase is the foundational stage of XR2Learn's Open Call 2, where the 10 selected sub-projects transition from their initial proposals to a concrete, executable technical and business roadmap. This phase is designed to ensure that the proposed XR-based solutions are perfectly aligned with the XR2Learn technical ecosystem and have a viable path to market.

3.1.1. Activities

During the Pilot Specification phase, sub-projects focused on building and fine-tuning their application concepts to ensure they address specific educational or training needs. Consortia also performed additional development or customization to effectively utilize XR2Learn technology. Finally, participants were required to prepare a detailed pilot specification deliverable alongside a tech-business presentation to outline their roadmap for the subsequent phases.

During the Pilot Specification phase, the OC2 winning teams were present at the XR2Learn's general assembly meeting held in Lugano, Switzerland in May 2025. The teams participated in a series of workshops dedicated to community building, stakeholder engagement and the application of the XR2Learn educational framework. Furthermore, they took part in a hands-on tutorial on the XR2Learn enablers led by the Maastricht University team.

Figure 9: PARTICIPATION OF THE OC2 SUB-PROJECTS IN THE LUGANO GENERAL ASSEMBLY, MAY 2025

3.1.2. Deliverables

The successful completion of this phase hinged on the submission of the D1: Detailed XR Pilots Specification in June 2025. This report acts as a technical blueprint and must include the following sections:

- **Motivation and Background:** A clear explanation of the technological gap the XR application intends to fill.
- **Educational Scenarios:** A detailed mapping of how the XR application will be used in real-life teaching or training settings.
- **Detailed Technical Design:** The architecture of the proposed application, including how it integrates with the XR2Learn platform.
- **Impact Assessment:** A study of the economic and business potential, outlining how the project will achieve sustainability

All sub-projects within the OC2 submitted successfully the D1: Detailed XR Pilots Specification and therefore the review process could proceed.

3.1.3. Review and selection

At the end of the third month, the projects underwent a detailed Pilot Specification Phase Review. This is a competitive gate where only the top-performing projects move forward. The review was scheduled after the end of M3 via teleconference and was conducted by two independent external experts and one XR2Learn moderator. Projects are scored on three specific dimensions: Technical Excellence (FTES), Pilot Scale/Potential (FPES), and Market Readiness/Business Potential (FBES). The individual scores produced the average between the experts which are the final scores (FTES, FPES, FBES) The 8 projects to proceed to the pilot execution phase were selected according to a ranking defined by their Final Evaluation Score (FES). The calculations for the final result of the Pilot Specification phase are calculated according to the following formula:

$$FES = 0.3 \cdot FTES + 0.4 \cdot FPES + 0.3 \cdot FBES$$

While all 10 projects that achieved an FES of 5.0 were considered to have successfully completed the phase and received the €30.000 voucher, only the top eight projects were selected to enter the Pilot Execution phase.

The Pilot Specification phase essentially served as a "de-risking" period, ensuring that only projects with high technical feasibility and strong market potential proceed to the resource-intensive pilot execution stage. The ranking table after the Pilot Specification Phase is shown below, where the top 8 projects that continued to the Pilot Execution phase are clearly visible:

Table 3: RANKING OF OC2 AFTER THE PILOT SPECIFICATION PHASE

Project	Phase 1 - Scores
NEONATAL	10
XR2LabTrain	9.7
XRTwinScape	9.3
RTXRoom	8.7
EcoDriveXR	8.6
X-DE-MAN	8.6
Portal-XR	7.6
XPOTLESS	7.3
XCC	7.0
XRive	6.7

3.2. Pilot Execution Phase

Following the successful selection from the specification phase, the top eight projects entered the Pilot Execution phase, planned to be the primary technical and experimental core of the programme. This phase spanned across seven months, beginning in July 2025 and concluding in January 2026 and had two sub-phases.

3.2.1. Activities

The central objective of this second phase in XR2Learn's OC2 was for each consortium to implement large-scale pilots of their XR applications within real-life settings to validate user acceptance and effectiveness. During this execution, the sub-projects were expected to advance their software to a high state of maturity, specifically reaching a TRL greater than 7 and a MRL of 4 or higher. This phase was divided into two sub-phases with two different review processes, one in M6 to assess the preliminary pilot results and one in M10.

The first three months (first sub-phase) focused on the rollout of the pilot and the gathering of preliminary data. At the end of the sixth project month (September 2025), a remote review was conducted by two external experts and a consortium moderator.

Sub-projects must submit a progress report (D2) that provides a detailed analysis of the pilot approach, screenshots of the application in use, and early experimental results. A successful evaluation of this mid-term progress triggers a lump sum payment of EUR 100.000.

The remaining four months (second sub-phase) were dedicated to completing the large-scale testing and finalizing the business strategy. This period culminates in a final review - at project month 10 (January 2026). Consortia were required to deliver a comprehensive validation report (D3) that includes results from the large-scale trials and specific data regarding the gender balance of trainees involved in the pilot. Additionally, projects had to produce a 5-to-10-minute video (D4) demonstrating the XR application and its impact. Satisfactory completion of these requirements resulted in the release of a second EUR 100.000 payment. At the close of this phase, the external experts ranked the projects based on their final pilot results and exploitation strategies to select the top three sub-projects that will advance to the final Growth phase of the XR2Learn's second open call procedure.

OC2's participation in the XR2Learn General Assembly in Maastricht in November 2025 provided a critical platform for the sub-projects to showcase their technological advancements and pilot results to the broader consortium. These high-stakes reviews were essential for projects to demonstrate their successful integration of the XR2Learn ecosystem and their readiness for commercial expansion.

Figure 10: OC2 SUB-PROJECTS TOGETHER WITH THE XR2LEARN'S CONSORTIUM IN MAASTRICHT, NOVEMBER 2025

3.2.2. Deliverables

During the first sub-phase of the execution period, projects were required to submit deliverable D2, titled "Initial Pilot Execution Results," by September, 2025. As the projects transitioned into the second sub-phase, they had to complete two additional deliverables by January 2026: D3, which focuses on "Pilot Execution Validation," and D4, which consists of the "Project Video".

3.2.3. Review and selection

The review and selection processes for the Pilot Execution phase were governed by a series of rigorous evaluations conducted by a committee of independent external experts and consortium moderators. During the initial review of sub-phase 1, the experts assessed the project's progress and provided a formal review report that includes detailed comments and recommendations, specifically stating whether the implementation is considered successful or not.

As the projects moved into the review for sub-phase 2, a successful evaluation depended on the satisfactory delivery of all required documents, a formal presentation, and a live demonstration of the XR solution to the committee, all of which had to be accepted to result in the successful completion of the entire Pilot Execution phase. Following these reviews, the final selection of the three sub-projects permitted to proceed to the Growth phase is determined by a ranking based on their pilot results, business and exploitation strategies, and the overall quality of the D4 "Project Video". Each committee member provided a score, and the average of these individual marks constituted the Final Pilot Execution Evaluation Score (FEES), which served as the definitive metric for the final ranking, which after the Pilot Execution Phase looks like this:

Table 4: RANKING OF OC2 PROJECTS AFTER THE PILOT EXECUTION PHASE

Project	Phase 2 - Scores
NEONATAL	9
X-DE-MAN	9
Portal-XR	9
XR2LabTrain	8.3
XRTwinScape	8.3
RTXRoom	8.3
EcoDriveXR	8.3
XPOTLESS	7.6
XCC	-
XRive	-

3.3. Growth Phase

Following the completion of the Pilot Execution phase, the remaining three sub-projects entered the Growth phase, which lasted for two months from February 2026 to March 2026. The primary objective of this final stage was the commercialization and long-term sustainability of the developed XR applications. During this period, the sub-project consortia were required to participate in various industry events and conduct face-to-face meetings with potential investors to finalize their business and market plans.

3.3.1. Activities

Participation in specific XR2Learn events, such as project meetings, workshops, or reviews, was mandatory for demonstrating the XR tools and applications; failure to participate in these requested sessions results in automatic termination of the sub-project. One week before the end of the phase, the sub-project coordinator had to submit deliverable D5, "Exploitation & Sustainability," which is a comprehensive report describing all dissemination, exploitation, and commercialization activities, as well as an assessment of the project's sustainability potential.

During the Growth phase of the XR2Learn Open Call 2, the top three sub-projects - NEONATAL, X-DE-Man and Portal XR - engaged in high-impact dissemination activities to ensure market readiness and long-term sustainability. A central element of this phase is the participation in Laval Virtual 2026, Europe's premier exhibition for immersive technologies, where the sub-projects were featured at a joint XR2Learn booth alongside sister projects such as MotivateXR and MASTER. At this event, the teams provided physical demonstrations of their mature XR applications to an audience of over 5,000 professionals, researchers, and students, while simultaneously engaging in networking sessions and technical conferences to build partnerships with potential industrial adopters and investors.

Figure 11: XR2LEARN AND OC2 PROJECTS AT LAVAL VIRTUAL 2026

3.3.2. Deliverables

Deliverable D5, "Exploitation & Sustainability," served as the final administrative and strategic milestone of the Growth phase. It is a comprehensive report designed to assess the long-term viability of the sub-project after the XR2Learn funding period ends. The report had to provide detailed information regarding the following key areas:

- **Dissemination Activities:** A record of how the consortium promoted the project's goals and outcomes to various audiences. This typically includes participation in events like AWE EU, Laval Virtual, or other industry-specific exhibitions to increase market reach and visibility.
- **Exploitation and Commercialization:** A detailed description of the activities undertaken to engage new customers, partners, or investors. This includes the results of face-to-face meetings with potential investors conducted during the two-month Growth phase.
- **Sustainability Potential:** A rigorous assessment of the business strategy to ensure the XR application's long-term viability. This includes replication analysis and finalized market plans intended to achieve growth and market uptake.

The submission of deliverable D5 was a mandatory prerequisite for the final project review. This report had to be submitted at least one week before the end of the Growth phase, which concluded in March 2026. Adherence to this timeline is critical - if D5 was not submitted on time, the final Growth phase review would be cancelled, the phase would be officially deemed unsuccessfully completed, and the sub-project would be automatically terminated without any financial compensation. Final compensation was strictly contingent upon the external experts' acceptance of the D5 deliverable, which is required to release the final €65,000 lump sum payment. Furthermore, D5 holds significant weight for the "Top #1" prize, as the quality of the results documented in the report, combined with the project's final presentation, informed the XR2Learn consortium members' vote for the "Top #1 project". The sub-project that secured the most votes based on these documented outcomes was honoured with an additional €5,000 prize voucher.

3.3.3. Review and selection

The final review of the sub-projects occurred at the conclusion of the 12-month programme in March 2026 to determine if the Growth phase has been completed successfully. This evaluation was performed by a committee consisting of two independent external experts, a representative of each project partner and one XR2Learn consortium member acting as a moderator. During the review the consortium provided a presentation of their outcomes followed by a question-and-answer session.

The experts examined whether the sub-project has met the required standards for dissemination and exploitation as documented in the D5 "Exploitation & Sustainability" report. A positive review report and the acceptance of all deliverables resulted in the successful conclusion of the phase and the release of the final €65.000 payment. Following the technical review, all XR2Learn consortium members participated in a voting process to select the "Top #1 project". Each member had up to two equal votes, and the sub-project that received the maximum number of votes was awarded an additional €5.000 prize voucher.

The final review of the sub-projects, NEONATAL, X-DE-MAN and Portal-XR, was organized on April 2nd, 2026 through a video conference. It marked the conclusion of the 12-month programme in March 2026 to determine if the Growth phase has been completed successfully. This evaluation was performed by a committee consisting of two independent external experts and a representative of each XR2Learn consortium member. The review lasted about 2 hours, during which the OC2 consortia provided a presentation of their outcomes followed by a question-and-answer session.

Before the review, the experts examined whether the sub-project has met the required standards for dissemination and exploitation as documented in the D5 "Exploitation & Sustainability" report. A positive review report and the acceptance of all deliverables result in the successful conclusion of the phase and the release of the final €65.000 payment.

Following the technical review, all XR2Learn consortium members participate in a voting process to select the "Top #1 project". Each member has up to two equal votes, and the sub-project that receives the maximum number of votes is awarded an additional €5.000 prize voucher. This final selection was based on which project demonstrated the highest potential for long-term market impact and successfully finalized their business and market plans. According to the voting, the XR2Learn selected the NEONATAL team as Top #1 project and awarded the team with an additional voucher of €5.000.

Project	Phase 3 Final Review Prize winner
NEONATAL	

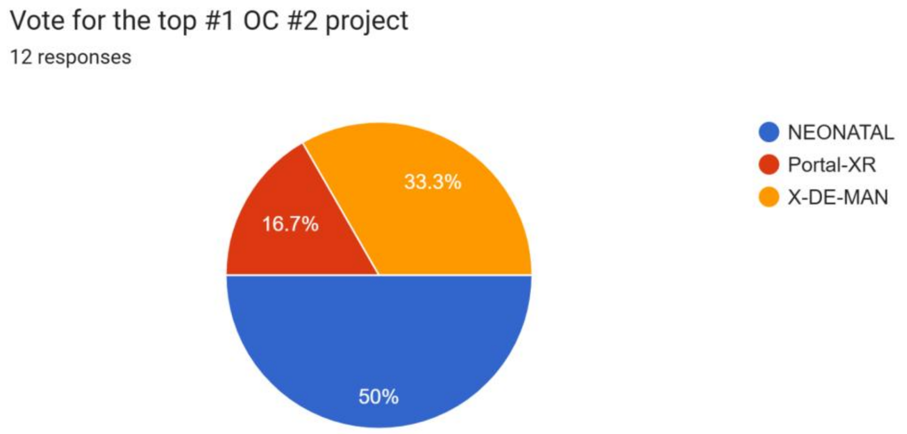

Figure 12: VOTING STRUCTURE FOR TOP #1 OC2 PROJECT

4. Results

To provide a comprehensive view of the practical outcomes generated during this acceleration programme, the table below consolidates the technical, educational, and scientific contributions of each sub-project evaluated under XR2Learn's OC2. This overview details the precise technical components, specialized enablers, and interactive beacon applications developed to support Industry 5.0 and human-centric training scenarios. Furthermore, it maps the concrete educational impact by tracking the total number of unique trainees reached across clinical and industrial pilot sites, alongside open-source marketplace contributions, lesson plans integrated with the EIT Manufacturing Academy, and peer-reviewed scientific publications.

Table 5: XR2LEARN' OC2 PROJECTS SUMMARY OF CONTRIBUTIONS

Project Acronym	Technical Components & Enablers	Beacon Applications & Learning Journeys	Learning Content & Marketplace Contributions	Trainees Reached
X-DE-MAN	• Immersive VR Training App (Meta Quest 3) • Mobile/AR operational Support "Beacon App" • Structured XML-based DDM Library • CAD-to-DDM synchronization workflow via LeanDfD software	• Two Comprehensive Journeys (Introduction and Advanced) • Dual Modes: Guided Disassembly walkthroughs and Free Assessment Mode • Contextual QR-code tracking and Graphical Disassembly Maps (GDMs)	• Structured XML Library for generating digital disassembly maps hosted on the Marketplace • Free educational slides and flashcards published on the Marketplace	Validated with industrial operators and end-users at Electrolux and Simonelli Group
Portal-XR	• Five-layer architecture (Unity3D, Authoring, Analytics, LRS, and Runtime) • Physics-based Crane Simulation Engine • xAPI-based Learning Record Store (LRS) • Multimodal Emotion Classification and Analytics Systems	• Three core Beacon Applications spanning 11 interactive VR scenarios • Specific training journeys for Ship-to-Shore (STS) crane operation, hazardous goods handling, and emergency fire response	• Reusable high-fidelity digital twins of cranes, cargo containers, and firefighting tools • Learning units and materials uploaded to the EIT Manufacturing Academy	~150 port operation users at the Thessaloniki Port Authority

NEONATAL	• Fully immersive standalone VR application (Unity/Meta Quest 3) • Custom Universal State Machine script • Integrated Emotion Classification (Enabler 5) and Adaptive Personalization (Enabler 6)	• Scenario 1: Neonatal Resuscitation for breathing difficulties • Scenario 2: ABCDE Clinical Assessment protocol • Custom Adaptive Difficulty system (Beginner, Intermediate, Advanced)	• Custom Universal State Machine script published as open-source resource on the Marketplace • VR Clinical Training lesson plans uploaded to the EIT Manufacturing Academy	100 healthcare professionals in Danish clinical settings
XR2LabTrain	• Low-latency end-to-end data pipeline • Computer-vision-based REBA Ergonomic Assessment tool • Interaction-driven Learner Proficiency Enabler (LPE) • Grid-based inspection path tracking	Structured three-step user learning journey (Observe virtual expert, Guided practice with "expert footprints", Independent defect identification)	• Digital Defect Library containing representative manufacturing defects (scratches, bulges) • Modular training packages integrated into the EIT Manufacturing Academy	Validated with early adopters, vocational trainees, and industrial experts at BRP-Rotax
XRTwinScape	• Cloud-native software ecosystem • AI/Gaussian Splatting 3D reconstruction pipeline • Lesson Management dashboard and Spatial Annotation Editor • XR Player application for web browsers and Meta Quest 3 • Integration with the XR2Learn Personalization Enabler	• Contextualized, scenario-based virtual training paths • Embedded multimedia lessons mapped to pedagogical frameworks (ASSURE, TPACK, Bloom's Taxonomy)	• Reusable Lesson file format (.tsl) combining Gaussian Splatting models with JSON annotations • Technical source blocks shared via a public GitHub repository	Validated with vocational students, remote remote users, and remote remote groups at the University of Salerno
XPOTLESS	• Unity and Docker-based modular architecture • Instant Real-time Full-Hand Gesture Capture component • PC-based Voice Audio Emotion	• Mobile 360° Learning Module for remote self-paced theory • Immersive VR/MR Training Module with 3 industrial hygiene scenarios	• Custom Gesture Capture enabler uploaded to the Marketplace • Sector-specific 3D assets of industrial food-processing	~80 agrifood sector operators and regional stakeholders

	Recognition module • Redis-driven hybrid messaging bus and Azure PlayFab/Playmaker sync pipeline	(PPE Placement, Dry Cleaning, Detergent/Disinfection)	equipment and cleaning tools published on the Marketplace • Custom training paths approved for the EIT Manufacturing Academy	
RTXRoom	• Microsoft HoloLens 2 and MRTK3 gesture/voice/gaze interface • In-house 3D Narrative and Assembly Sequence Editor • Low-latency Remote Expert Live Streaming and annotation interface • HoloLens 2 head/hand movement tracking system mapped to a CNN1D emotion classifier via Redis	• Scenario 1: Individual Training for self-paced aluminium frame assembly • Scenario 2: Collaborative Training for multi-user synchronized assembly and peer mentoring	• Granular library of 3D industrial tools (e.g., electric drills) published for free on the Marketplace • Open RTXRoom Familiarization and Navigation Course published on the EIT Manufacturing Academy	60 unique industrial participants (technicians, trainees, supervisors, and instructors)
EcoDrive XR	• AI-powered 2D-to-3D Photorealistic Holographic Teacher Reconstruction engine • Core Unity workflow integrated with the XR2Learn INTERACT enabler for interactive cable/object routing	• Structured 7-Module VR Learning Journey (Factory Onboarding, Safety Protocols, Battery Production, Life-size Volvo EV Assembly, Sustainability, Quiz)	• New Enabler Contribution 1: Holographic Teacher API Unity plugin • New Enabler Contribution 2: 3D Object Manipulation module • Reusable industrial assets on the Marketplace • EcoDrive XR Familiarization Course on the EIT Manufacturing Academy	100 vocational students across two distinct academic sites in Slovakia
XRive	Concluded at the conceptual blueprint level; did not advance to Pilot Execution	Conceptual 3-Module Automotive Curriculum focused on hazard perception and HMI evaluation	Technical design specifications for hardware-agnostic Head-Up Display (HUD) and AR-glasses warning	N/A

			interfaces	
XCC	Concluded at the design and specification level; did not advance to Pilot Execution	Multi-layered networking monitoring dashboard concept for direct supervisor tracking	Planned generic monitoring SDK for multiplayer simulator synchronization	N/A

4.1. X-DE-MAN

Figure 13: X-DE-MAN logo

X-DE-MAN is a project focused on improving operator efficiency, safety, and resilience in the de-manufacturing sector, particularly for mechatronic products such as consumer electronics and household appliances, through the use of XR technologies. The project is developing a comprehensive XR-based platform that combines digital tools, including disassembly maps and 3D CAD product models, with a competency-based learning approach. This enables operators to develop practical skills within immersive virtual environments before performing tasks in real industrial settings.

The platform is designed to be interoperable with existing industrial systems, such as CAD tools, while also supporting circular economy objectives by promoting recovery, reuse, and remanufacturing processes. At the core of the X-DE-MAN solution are two main components: the XR App, which provides a VR-based environment for simulating disassembly procedures of target components, and the Beacon App, which delivers real-time, step-by-step assistance during physical disassembly operations through QR code interaction. This combined approach to training and operational support helps reduce errors, improve knowledge retention, and supports Industry 5.0 principles by enabling more human-centric and sustainable manufacturing processes.

The project is a collaboration between MORE srl, acting as technology provider and project coordinator, and the University of Parma (UNIPR), contributing expertise in disassembly processes and academic research. The initiative is further supported by industrial stakeholders including ELECTROLUX and SIMONELLI Group. The project’s outputs include both an open-source training environment and a professional-grade platform with commercialization potential, aiming to support scalable adoption among European SMEs operating in the de-manufacturing sector.

X-DE-MAN was selected as one of the 10 winning projects of the XR2Learn Open Call 2, launched to support SMEs and innovators in developing advanced XR-based educational and training applications. The sub-project participated in a structured 12-month support programme running from 1 April 2025 to 31 March 2026, organized into three sequential phases: Pilot Specification, Pilot Execution, and Growth.

During the Pilot Specification phase, X-DE-MAN focused on defining the technical architecture of its XR-based de-manufacturing training platform, adapting XR2Learn technologies and enablers to its industrial use case, and preparing a comprehensive pilot specification and business plan. The project successfully demonstrated the feasibility and innovation potential of its immersive training solution, which combines digital disassembly workflows, VR simulations, and real-time operational support for industrial operators.

Following the evaluation of the specification phase deliverables, X-DE-MAN was selected among the top eight projects to progress to the Pilot Execution phase. During this stage, the consortium implemented and validated the platform with real industrial stakeholders and end users, demonstrating the effectiveness of the XR-based training approach in improving operator training, knowledge retention, and sustainable de-manufacturing practices. The project also refined its exploitation strategy and commercialization plans in preparation for broader market adoption.

As a result of its strong technical results, industrial relevance, and market potential, X-DE-MAN was ultimately selected as one of the top three XR2Learn Open Call #2 projects to advance to the Growth phase. This phase focused on strengthening the project's business development activities, market readiness, dissemination efforts, and long-term sustainability strategy, positioning X-DE-MAN as one of the most promising XR2Learn innovations for future industrial deployment and commercialization.

4.1.1. Technical results and utilization of XR2Learn ecosystem

The primary technical outcomes of the project include:

Core Software Applications

- **VR Training Application:** An immersive environment (tested on Meta Quest 3) that allows operators to practice component disassembly. It features:
    - Dual Operational Modes: A "Guided Disassembly" mode with step-by-step walkthroughs and a "Free Mode" for autonomous practice and skill assessment.
    - Adaptive Environments: Two distinct virtual settings - an industrial "Dismantling Center" and a "Domestic Kitchen" - to simulate different real-world challenges.
    - Visual Guidance Systems: Implementation of a light-blue "outliner" to highlight target components, tools, and connection points, which turns green upon correct task completion.
- **Beacon App**: A mobile support tool designed for real-world operations that provides:
    - Contextual Guidance: Scans QR codes on physical appliances to retrieve specific digital disassembly instructions from a cloud server.
    - Dual-Mode Support: Offers "Graphical Disassembly Maps" (GDMs) for step-by-step visual aid and an "Augmented Reality (AR) Mode" for navigating 3D models of the appliance.

  - Progress Tracking: Synchronizes with the VR app to allow users to review their individual performance metrics and simulation reports on a mobile device.

Digital Infrastructure and Data Models

- **Digital Disassembly Maps (DDMs)**: Creation of a structured XML-based data format that captures component hierarchies, sequence dependencies, and tool requirements.
- **Standardized DDM Library:** A centralized repository of reusable elements, including:
  - Liaisons and Connections: Standardized definitions for mechanical and electrical joints (e.g., threaded, press-fit) with associated standard disassembly times.
  - Tools and Actions: Categorized lists of manual tools (e.g., specific screwdriver types) and elementary actions based on the MOST method (e.g., lift, rotate, grab).
- **CAD-DDM Synchronization**: Successful validation of synchronizing 3D CAD models (in .glb format) with XML disassembly instructions within the XR workflow.

Performance Assessment and Validation

- **Evaluation Metrics**: Development of a system to track trainee performance based on the number of controller clicks versus the minimum required and the time taken per step.
- **Proficiency Scaling:** Implementation of a five-star rating scale (from "Poor" to "Excellent") calculated through a weighted average of step scores, constrained by the lowest-performing step.
- **Initial Pilot Success:** Successful deployment in representative environments (using a kitchen hood use case) with industrial stakeholders like Electrolux and Simonelli Group.

Learning Journeys

- **Pedagogical Framework:** Two structured "Comprehensive Journeys" (Introduction and Advanced) were developed to transition operators from basic VR navigation to autonomous disassembly of complex mechatronic components.

The X-DE-MAN project utilized the XR2Learn ecosystem as a foundational framework to develop, synchronize, and prepare its de-manufacturing training platform for commercial use. The project leveraged several specific components of this ecosystem to ensure its tools are standardized, interoperable, and market-ready.

Integration with XR2Learn Components

- **XR2Learn Marketplace and Distribution:** The project uses the ecosystem's marketplace as its primary distribution channel for both commercial and educational assets. Specifically, the XML Library, a core technical component for generating digital disassembly maps (DDMs), is hosted here and priced in cryptocurrency (0.010 ETH) to align with ecosystem standards. Additionally, free educational materials, such as slides and flashcards from the training modules, are distributed via the marketplace to encourage community engagement.

- **Cloud Infrastructure and Interoperability**: X-DE-MAN utilized the ecosystem's cloud-based backend to ensure seamless synchronization between different hardware. For instance, performance data collected from a trainee using the VR App (on a Meta Quest 3) is stored on a central server, allowing the same user to later review their progress and simulation reports via the mobile Beacon App. This infrastructure ensures that product models and disassembly instructions remain updated across all devices.
- **Pedagogical and Competency Frameworks**: The project aligned its "Comprehensive Learning Journeys" with the ecosystem's Competence-Based Learning (CBL) goals. These structured paths—ranging from introductory VR navigation to advanced mechatronic disassembly—are designed to bring operators to specific proficiency levels validated by the ecosystem's assessment standards.
- **Technical and Regulatory Standards**: To ensure compatibility within the wider European XR and manufacturing landscape, X-DE-MAN developed its data models to be compliant with ecosystem-supported standards, specifically the CEN-CENELEC 4555X series. This alignment ensures that the digital disassembly maps address requirements for recyclability, recoverability, and reusability.
- **Standardized Hardware and Software Tools**: The project optimized its immersive environment for the Meta Quest 3, adhering to the ecosystem's recommended interaction designs. It also integrated the LeanDfD software tool within the workflow to automate the creation of DDMs directly from CAD models, ensuring the technical pipeline remains efficient and scalable.

4.1.2. Dissemination and UVP

The dissemination strategy and Unique Value Proposition of the X-DE-MAN project focus on positioning the platform as a scalable XR-based solution for operator upskilling, sustainable de-manufacturing, and Industry 5.0 transformation. Dissemination activities targeted both academic visibility and engagement with industrial stakeholders, technology providers, and potential adopters within the manufacturing and circular economy sectors.

From an academic perspective, the project established a strong scientific dissemination pipeline through research publications and educational outreach. Two papers were accepted for presentation at leading CIRP conferences in Japan in 2026, addressing XR-based virtual disassembly and XR-driven operator upskilling for Industry 5.0 environments. In parallel, a journal paper is being prepared for submission to *Advanced Engineering Informatics* (Elsevier), focusing on the X-DE-MAN platform and its contribution to immersive industrial training.

The project was also showcased at major **industrial and XR events**, including SPS Italia 2025 and Laval Virtual 2026, where the consortium demonstrated the platform to industrial stakeholders, XR professionals, and technology providers. Dedicated **seminars and demonstrations** were additionally organized with companies such as ELECTROLUX and NUOVA SIMONELLI, enabling operators to test the VR environment and provide practical feedback. Engagement activities were also initiated with external stakeholders including AIRBUS SAS, E.G.O. GmbH, and recycling companies such as S.E.Val Srl and Relight Srl.

X-DE-MAN also developed a project introductory video and demo video, available on the XR2Learn YouTube channel.

Figure 14: X-DE-MAN SHOWCASING THEIR SOLUTION AT LAVAL VIRTUAL 2026

The **Unique Value Proposition** of X-DE-MAN lies in its ability to combine immersive XR technologies, competency-based learning, and sustainable industrial practices into a unified training ecosystem. The platform integrates digital disassembly maps, CAD-based product models, immersive VR simulations, and real-time operational guidance to support both virtual and physical disassembly activities.

A key differentiator is the platform's dual-mode approach: the XR App enables immersive VR-based training for disassembly procedures, while the Beacon App provides step-by-step assistance during real-world operations through QR-code-based guidance. This combination reduces errors, improves knowledge retention, and supports safer and more efficient industrial workflows.

The project also promotes circular economy and Industry 5.0 principles by supporting recovery, reuse, and remanufacturing processes for mechatronic products. Through modular licensing models and structured learning journeys developed in collaboration with EIT Manufacturing, X-DE-MAN delivers scalable and market-oriented XR training solutions for industrial operators, engineering students, and SMEs.

4.2. Portal-XR

Figure 15: PORTAL-XR logo

The Portal-XR project aims to transform how port logistics personnel are trained through the application of advanced XR technologies supported by XR2Learn. In an industry characterized by high operational complexity and significant risk factors - ranging from hazardous materials to heavy machinery - the capacity to equip workers with critical skills in a safe, immersive, and realistic environment is of paramount importance. Portal-XR rises to this challenge by providing a cutting-edge XR training platform that combines the fidelity of digital twin technology with the responsiveness of real-time simulation, delivering a comprehensive solution tailored to the operational and educational demands of modern port environments.

At the core of the project is a modular platform architecture integrating high-fidelity 3D modelling, immersive simulation environments, and adaptive educational scenarios designed according to established pedagogical principles. The solution is compatible with INTERACT, the XR2Learn authoring tool, enabling dynamic content creation, scenario management, and future extensibility by training providers and industry stakeholders.

The project is implemented through the collaboration of three specialized partners: BYTELEPA Solutions, acting as the ICT and technology provider; the University of Peloponnese, contributing expertise in XR pedagogy and instructional design; and the Thessaloniki Port Authority, supporting industrial validation and real-world testing. Over a 12-month development cycle, the consortium follows an iterative methodology structured around four main phases: requirements analysis and system architecture design, XR content and digital twin development, edge synchronization and platform integration, and finally piloting, validation, dissemination, and exploitation activities.

During the **Pilot Specification phase**, the project adapted XR2Learn technologies and enablers to the maritime logistics sector, defining the architecture of its immersive XR training platform for port operations and industrial safety scenarios. The consortium also prepared a pilot specification and business plan demonstrating the project's technical and market potential. Following a successful evaluation, PORTAL-XR advanced to the Pilot Execution phase as one of the top eight projects. During this phase, the platform was implemented and validated with real users and stakeholders, including the Thessaloniki Port Authority, focusing on training scenarios such as hazardous materials handling and Ship-to-Shore (STS) crane operations.

Due to its strong technical results, industrial relevance, and commercialization potential, PORTAL-XR was ultimately selected as one of the top three XR2Learn Open Call 2 projects to progress to the **Growth phase**, where the consortium focused on market readiness, dissemination, and exploitation activities.

4.2.1. Technical Results and utilization of XR2Learn ecosystem

The technical results of the PORTAL-XR project include the development of high-fidelity virtual simulations, the integration of specialized software enablers, and a modular architecture designed for industrial port training.

Core Technical Infrastructure

- Modular Architecture: The system is built on a five-layer architecture: a Presentation Layer (Unity3D interfaces), Simulation Layer (physics and logic controllers), Authoring/Content Management Layer (INTERACT tool), Analytics Layer (performance metrics), and VR/AR Runtime.
- New Technical Enabler: The project introduced a new physics-based crane simulation engine to provide high-fidelity training for Ship-to-Shore (STS) crane operations.
- Edge Integration: The platform utilizes edge computing to synchronize digital twin models with real-world sensor data from port equipment.
- Learning Record Store (LRS): This component captures xAPI-based analytics, allowing for adaptive instruction and the tracking of learner performance.

Developed Content and Simulations

- Immersive Simulations: The project produced 11 interactive VR scenarios distributed across three "Beacon Applications": STS crane operation, hazardous goods handling, and fire/emergency response.
- High-Fidelity Digital Twins: Interactive digital twins were created for specialized equipment, including cranes, cargo containers, and firefighting tools.
- Dynamic Environmental Simulation: VR scenarios include real-time environmental variables, such as weather simulation (fog, rain, wind) and shifting vessel movements to mimic real-life sea swells.
- Bilingual Support: The technical content was developed with multilingual accessibility, featuring English voiceovers and Greek subtitles.

Integrated Tools

- XR2Learn INTERACT Enabler: Portal-XR fully integrated the INTERACT authoring tool, which allows designers to create dynamic scenarios and adjust difficulty based on learner progression.
- Performance Tracking: The system includes a Multimodal Emotion Classification System and an Analytics System to monitor and suggest improvements for trainee performance.

The Portal-XR project utilized the XR2Learn ecosystem primarily through the integration of technical enablers, pedagogical frameworks, and the project's specialized authoring tool to create a modular training platform.

Specific XR2Learn Components Used

The project integrated several core components from the XR2Learn ecosystem:

- INTERACT Authoring Tool: This is the primary XR2Learn enabler utilized by Portal-XR. It allowed scenario designers and instructors to:
  - Define learning paths, instructional goals, and assessment checkpoints.
  - Configure dynamic training scenarios using drag-and-drop templates.
  - Adjust scenario difficulty based on learner progression and feedback.
- Learning Record Store (LRS): Used to capture xAPI-based learning analytics, which enables adaptive instruction and provides supervisors with performance dashboards.
- Evaluation Tools: The project used XR2Learn-specific evaluation tools for reporting and analyzing back-end data, such as learner performance metrics and engagement data.

Utilization of the XR2Learn Ecosystem

Portal-XR leveraged the broader ecosystem to ensure its solutions were pedagogically sound and technically scalable:

- Alignment with Educational Frameworks: The training modules were developed to align with XR2Learn's pedagogical standards, specifically utilizing the Revised Bloom's Taxonomy and European Qualifications Framework (EQF) to ensure measurable educational outcomes.
- Integration with EU Skill Frameworks: The project embedded indicators from DigComp 2.2 (digital skills), GreenComp (sustainability), and LifeComp (soft skills) into its VR scenarios, following the ecosystem's vision for holistic workforce upskilling.
- Deployment through the EIT Manufacturing Academy: Developed learning units and materials were uploaded to the EIT Manufacturing academy platform, which serves as a distribution channel within the ecosystem.
- Modular Technical Architecture: The system was designed as a five-layer architecture (Presentation, Simulation, Authoring, Analytics, and VR/AR Runtime) specifically to maintain compatibility with XR2Learn enablers like INTERACT.
- Introduction of New Enablers: In addition to using existing tools, the project contributed back to the ecosystem by developing a new physics-based crane simulation engine to provide high-fidelity training for Ship-to-Shore (STS) crane operations.

4.2.2. Dissemination and UVP

The PORTAL-XR team carried out a broad range of **dissemination and communication activities** aimed at promoting its immersive XR training platform for port operations and industrial safety scenarios. These activities targeted academic and industrial stakeholders, including port authorities, training providers, educational institutions, and XR communities.

From an academic perspective, the University of Peloponnese (UoP) disseminated scientific findings, pedagogical methodologies, and technical approaches through publications, webinars, and outreach activities. BYTELEPA additionally maintained a commercial online presence featuring demonstration videos and presentation materials showcasing the platform's key training scenarios and use cases.

The project was also showcased at major XR and industrial events, including Laval Virtual 2026, where PORTAL-XR demonstrated its immersive training capabilities alongside the XR2Learn consortium to XR professionals, industrial stakeholders, and technology providers from across Europe. This participation increased the project's visibility within the international XR ecosystem and facilitated networking with potential adopters and collaborators.

Dissemination activities further included stakeholder engagement within the Thessaloniki Port Authority (ThPA), where internal communication channels were used to recruit participants and raise awareness of the pilot activities involving approximately 150 users. Training materials and educational content developed during the project were also uploaded to the EIT Manufacturing Academy platform to support broader educational outreach and long-term accessibility.

To support knowledge sharing and future adoption, the consortium developed shared repositories and released selected platform components under open-source licensing schemes. In parallel, business development and exploitation activities were conducted to strengthen the long-term sustainability of the platform, with the modular and hardware-agnostic architecture promoted as a scalable solution adaptable to different industrial environments and geographic regions.

PORTAL-XR has also recorded a project introductory video and demo video available on the XR2Learn YouTube channel

Figure 16: A SCREENSHOT OF THE PORTAL-XR INTRODUCTORY VIDEO

The **Unique Value Proposition** of the PORTAL-XR project lies in its ability to transform traditionally resource-intensive and high-risk port training into a safe, immersive, and data-driven digital learning experience. By combining advanced XR technologies with established pedagogical frameworks, the platform introduces a new approach to workforce training and skills development within the maritime logistics sector.

A key value driver of the platform is its ability to reduce training costs by minimizing the need for physical equipment usage, on-site supervision, and operational downtime. At the same time, PORTAL-XR enables workers to safely practice high-risk procedures, such as hazardous materials handling, emergency response, and Ship-to-Shore (STS) crane operations within realistic virtual environments without real-world safety risks.

The platform also supports flexible and on-demand training approaches, accelerating onboarding and upskilling processes while improving learner engagement, practical skill acquisition, and knowledge retention compared to traditional training methods.

From a technical perspective, PORTAL-XR integrates high-fidelity digital twins of port infrastructure and equipment, supported by physics-based simulation engines reproducing realistic operational behaviors. The training modules are aligned with European competency frameworks such as DigComp 2.2, GreenComp, and LifeComp, while also addressing international maritime safety regulations including IMO, SOLAS, and IMDG standards.

Another important differentiator is the platform's modular and hardware-agnostic architecture, enabling deployment across various XR devices and training environments. Through integration with the XR2Learn INTERACT authoring tool, the platform additionally supports adaptive learning pathways, real-time performance analytics, and personalized feedback mechanisms to better address individual learner needs and competency gaps.

4.3. NEONATAL

Figure 17: NEONATAL logo

NEONATAL – Simulated Neonatal Resuscitation Training for European Healthcare Workers – uses Virtual Reality (VR) technologies to improve the skills, decision-making capabilities, and emotional resilience of healthcare professionals in neonatal emergency situations. The project creates immersive and realistic training scenarios that allow healthcare workers to practice neonatal resuscitation procedures in a safe, controlled, and repeatable virtual environment, ultimately aiming to improve outcomes in high-pressure clinical situations.

Neonatal resuscitation is one of the most critical and time-sensitive procedures in healthcare, with approximately 10% of newborns requiring some form of intervention at birth. Traditional training methods often rely on static manikin-based simulations that are resource-intensive and offer limited opportunities for repeated practice. NEONATAL addresses these limitations by providing flexible and scalable VR-based training that enables healthcare professionals to repeatedly practice emergency procedures and build confidence in realistic clinical scenarios.

The project builds upon a successful feasibility study and pilot conducted in Tanzania in 2024 across three hospitals, where the VR prototype was tested with 44 participants using Meta Quest 3 headsets. The results demonstrated the potential of VR as a cost-effective and adaptable training solution capable of improving skill acquisition and learner confidence.

With support from XR2Learn, NEONATAL adapted and refined two neonatal resuscitation training scenarios tailored to European healthcare contexts. The project was developed through a collaboration between Khora, an XR production studio specializing in immersive technologies, and Rigshospitalet's Department of Paediatrics and Adolescent Medicine. During the execution phase, the platform was validated with 100 healthcare professionals in Danish clinical environments to assess its effectiveness, usability, scalability, and market readiness.

By integrating XR2Learn enablers for emotional classification and personalization, NEONATAL also provides trainers with insights into learners' emotional responses during VR simulations, helping identify stress levels and areas where additional training may be required. Overall, the project demonstrates strong potential to improve the accessibility, quality, and cost-effectiveness of neonatal emergency training across Europe while supporting future expansion into additional healthcare training domains and international markets.

During the Pilot Specification phase, the consortium adapted XR2Learn technologies and enablers to the healthcare sector, defining the architecture of its VR-based neonatal emergency training platform and preparing a detailed pilot specification and business plan. The project focused on developing immersive and emotionally responsive neonatal resuscitation training scenarios tailored to European healthcare contexts.

Following a successful evaluation, NEONATAL progressed to the Pilot Execution phase as one of the top eight projects. During this phase, the platform was validated with healthcare professionals in clinical settings, demonstrating the effectiveness of immersive VR technologies for neonatal emergency training, decision-making support, and emotional resilience development.

Due to its strong technical results, educational value, and market potential, NEONATAL was selected as one of the top three XR2Learn Open Call #2 projects to advance to the Growth phase. The project was officially announced the **winner of the Growth** phase, recognizing its innovation potential, scalability, and readiness for future deployment within the healthcare training sector.

4.3.1. Technical results and utilization of XR2Learn ecosystem

The NEONATAL project delivered a fully immersive **Virtual Reality training application** designed to support neonatal emergency training for European healthcare professionals. The application was developed using the Unity game engine, while 3D assets and environments were created using Blender and Maya. The platform integrates the XR Interaction Toolkit together with a Playmaker-based state machine to manage scenario logic and user interactions within the virtual environment. To ensure accessibility, scalability, and ease of deployment across healthcare institutions, the solution was designed specifically for Meta Quest 3 standalone headsets, minimizing technical setup requirements and facilitating wider adoption in clinical and educational settings.

The project developed and refined two realistic training scenarios tailored to European healthcare practices. The first scenario focuses on neonatal resuscitation procedures for newborns experiencing breathing difficulties at birth, while the second addresses neonatal emergency management through the ABCDE clinical assessment protocol. Both scenarios were designed to provide healthcare professionals with realistic, repeatable, and high-pressure training situations that support the development of practical skills, clinical decision-making, and confidence.

A key technical achievement of the project was the integration of **XR2Learn Enablers 5 and 6**. Through Enabler 5 for sophisticated in-session emotion classification based on body-tracking data, the platform incorporated emotional inference technologies using a Shimmer3 GSR+ bio-tracking bracelet connected to an external PC, enabling the monitoring and analysis of stress, anxiety, and emotional arousal during training sessions. In parallel, Enabler 6 (personalization enabler) introduced adaptive personalization mechanisms capable of dynamically adjusting the training difficulty according to both user performance and emotional response. For example, the system could introduce unexpected complications during scenarios, such as an infant suddenly stopping breathing after successful resuscitation, creating more realistic and emotionally responsive training conditions.

To address technical limitations associated with existing scenarisation tools that required wired PC setups, the NEONATAL team developed a custom universal state machine within Unity capable of tracking complex scenario logic and training sequences. This solution was designed to be reusable and scalable, and the consortium plans to release it as an open-source Unity script through the XR2Learn Marketplace to support other XR developers and training providers.

The platform also incorporated several advanced user experience features aimed at improving immersion and learning effectiveness. These included interactive voice guidance, realistic sound effects such as crying infants and medical equipment, and haptic feedback mechanisms supporting procedural learning. In addition, the application introduced adaptive difficulty scaling through visual guidance indicators that changed according to the learner's experience level. Beginner users received continuous visual assistance, intermediate users received guidance only after inactivity, while advanced users completed scenarios without additional visual support. Following each session, the system generated qualitative performance reports incorporating reaction times, decision accuracy, and emotional response data captured through the integrated emotion classification tools, enabling both trainers and learners to evaluate progress and identify areas requiring further improvement.

4.3.2. Dissemination and UVP

The NEONATAL project carried out several dissemination, outreach, and ecosystem integration activities focused on advancing the use of Virtual Reality (VR) technologies for neonatal resuscitation and neonatal emergency training. A strong emphasis was placed on scientific dissemination, with the consortium preparing publications based on the project's randomized controlled trial for submission to peer-reviewed, open-access medical and technological journals. In parallel, the project's findings and technical developments were presented at national and international conferences to demonstrate the effectiveness, scalability, and educational value of the VR training modules.

The project also contributed to the broader European XR ecosystem through open-source and educational activities. The source code of the NEONATAL VR application was prepared for publication through **GitHub** and the **XR2Learn platform**, while the project's custom universal "State Machine" Unity script was planned for release on the XR2Learn Marketplace to support other developers in creating standalone VR training scenarios.

Figure 18: PICTURES FROM THE NEONATAL PILOT STUDY IN PEMBA, 2024

In collaboration with the EIT Manufacturing Academy, experts from Khora and Rigshospitalet developed **educational content and lesson plans** exploring the role of VR in clinical training, emergency simulations, rehabilitation, and healthcare system integration. These learning materials contributed to broader awareness and capacity-building around immersive healthcare education.

The project also actively engaged with healthcare institutions, municipalities, and governmental bodies across Europe to support innovation uptake and future deployment opportunities. As part of its dissemination efforts, NEONATAL participated in **Laval Virtual 2026** alongside the XR2Learn consortium, where the team showcased its VR neonatal training solution to XR professionals, healthcare stakeholders, and industry representatives.

NEONATAL has also developed a **project introductory demo video** available on the XR2Learn YouTube channel.

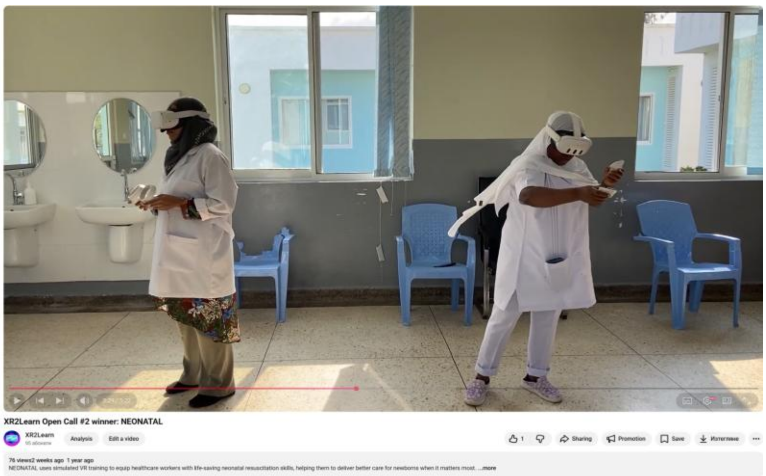

Figure 19: A SCREENSHOT OF THE NEONATAL INTRODUCTORY VIDEO

The **Unique Value Proposition** of the NEONATAL project lies in its ability to deliver an accessible, emotionally intelligent, and scalable Virtual Reality (VR) training solution for high-stakes neonatal emergencies. By combining immersive simulation technologies with adaptive learning and emotional analysis capabilities, the platform introduces a new approach to healthcare workforce training that supports both technical skill development and emotional preparedness.

A key differentiator of the project is its integration of XR2Learn emotional classification and personalization technologies, which enable trainers to monitor learners' stress levels and emotional responses during simulations. This allows the platform to deliver tailored training experiences that strengthen emotional resilience and improve decision-making under pressure - critical competencies in neonatal emergency care.

NEONATAL also addresses major accessibility and scalability challenges associated with traditional simulation-based healthcare training. By utilizing affordable standalone Meta Quest 3 headsets, the platform eliminates the need for expensive wired infrastructures and resource-intensive manikin-based simulations. This enables healthcare professionals to engage in flexible, high-frequency training sessions independently and without disrupting clinical workflows.

Another important innovation is the platform's adaptive difficulty system, which dynamically adjusts scenario complexity based on user performance and emotional data. For example, the application can introduce unexpected complications during a resuscitation scenario to better match the learner's competency level and create more realistic training conditions.

Finally, NEONATAL contributes to the broader European XR ecosystem through its open and standardized approach. Core technical components, including the project's custom universal "State Machine" Unity script, are being shared as open-source resources through the XR2Learn ecosystem. In addition, the training scenarios are aligned with European Resuscitation Council (ERC) guidelines, ensuring relevance, interoperability, and applicability across different European healthcare systems.

4.4. XR2LabTrain

XR2LabTrain

Figure 20: XR2LabTrain logo

XR2LabTrain is an XR-based training project focused on **improving workforce training and defect detection processes in manufacturing environments**. While automated inspection systems are widely used, human operators remain essential for identifying defects, validating quality, and making decisions during production workflows. However, visual inspection tasks are complex, cognitively demanding, and require extensive training.

To address these challenges, XR2LabTrain is developing a human-centric XR learning framework that enables workers to train within immersive and interactive manufacturing scenarios. The project builds upon data and workflows from the existing industrial inspection system ShowMe and transforms them into adaptive XR training modules and real-time assistance systems.

At the core of the project is a **data-driven ecosystem** that captures information from real production environments through sensors, IoT devices, quality reports, and manual inputs. This data is processed and converted into structured workflows, defect descriptions, and scenario-based XR learning experiences tailored to specific production tasks and learner profiles. The platform integrates Virtual Reality, Augmented Reality, and Spatial Augmented Reality technologies to support both immersive training and on-the-job assistance. Users interact with realistic simulations, perform inspection tasks, identify defects, and receive real-time feedback through visual, audio, and haptic cues. The system dynamically adapts training difficulty and learning pathways based on user performance and behavior.

By combining immersive training, adaptive learning, semantic data processing, and real-time industrial feedback loops, XR2LabTrain aims to deliver scalable and continuously updated XR training solutions aligned with modern manufacturing environments and Industry 5.0 principles.

During the Pilot Specification phase, the project defined the architecture of its XR-based industrial training platform focused on visual inspection and defect detection in manufacturing environments. The consortium adapted XR2Learn technologies and enablers to support immersive workforce training, ergonomic monitoring, and adaptive learning functionalities. Following a successful evaluation, XR2LabTrain advanced to the Pilot Execution phase as one of the top eight projects. During this phase, the consortium developed and validated immersive VR, AR, and Spatial Augmented Reality (SAR) training components designed to improve workforce skill acquisition, defect recognition, and operational support within industrial quality-control workflows. XR2LabTrain successfully completed its XR2Learn journey during the Pilot Execution phase, where the project demonstrated strong technical innovation and practical applicability within manufacturing and industrial training environments.

4.4.1. Technical results and utilization of XR2Learn ecosystem

The technical results of the XR2LabTrain project focused on the development of a data-driven XR training system for complex procedural and visual inspection tasks in manufacturing environments. At the core of the platform is an end-to-end data pipeline that manages information from real-world data capture through semantic processing to real-time visualization and interaction within XR environments.

The system utilizes **high-fidelity sensing technologies**, including OptiTrack marker-based tracking and 2D/3D cameras, to digitize expert knowledge, worker movements, and inspection procedures with minimal latency. Complex inspection workflows are segmented into modular procedural steps based on workpiece characteristics, expert movements, and viewing requirements, enabling the creation of structured and adaptive learning paths.

XR2LabTrain also integrated several technological enablers designed to improve training quality and workforce support. An ergonomic enabler based on **Rapid Entire Body Assessment (REBA)** scoring was developed using computer vision techniques and 2D camera data to monitor posture, body movements, and ergonomic risks in real time. In parallel, a **Learner Proficiency Enabler (LPE)** analyzed behavioral and performance metrics from VR interactions, including accuracy, efficiency, attention to detail, and procedural adherence, providing actionable feedback and performance analytics.

The project further developed immersive VR and AR training environments that visualize expert workflows and guide trainees through realistic inspection procedures using virtual tools, 3D overlays, and interactive assistance mechanisms. A structured user journey was implemented, allowing trainees to first observe virtual experts, then perform guided practice through "expert footprints," and finally complete independent defect identification tasks using integrated digital defect libraries.

To support procedural training, the project implemented modular workflow structures, including grid-based inspection paths and movement segmentation models that define specific viewing angles, head positioning, and field-of-view trajectories required for accurate inspection tasks. In addition, a digital defect catalogue containing representative manufacturing defects such as scratches, negative bulges, and positive bulges was integrated into the XR environment to support realistic defect recognition and training scenarios.

4.4.2. Dissemination and UVP

The XR2LabTrain project carried out a range of dissemination and exploitation activities aimed at increasing the visibility, market readiness, and long-term adoption potential of its XR-based industrial training solution. These activities focused on the communication of project results, refinement of the exploitation strategy, and preparation of market-oriented outputs such as a market readiness report and formal business strategy.

As part of its strategic growth roadmap, the project developed pilot demonstrators and Minimum Viable Products (MVPs) in collaboration with early adopters such as BRP-Rotax, providing proof-of-concept use cases for industrial stakeholders and manufacturing networks including Platform Industrie 4.0 and VDMA clusters. The consortium also focused on establishing a broader partner ecosystem involving vocational education institutions, industry associations, chambers of commerce, and XR technology providers.

To support wider adoption and accessibility, XR2LabTrain explored the integration of modular training packages into industrial learning marketplaces and digital competence platforms, including the EIT Manufacturing Academy. In parallel, the project contributed to discussions around standardization and policy frameworks related to XR-based industrial training, targeting organizations such as ISO and CEN-CENELEC to strengthen credibility and facilitate future uptake.

XR2LabTrain has also developed a **project introductory video** available at the XR2Learn YouTube channel.

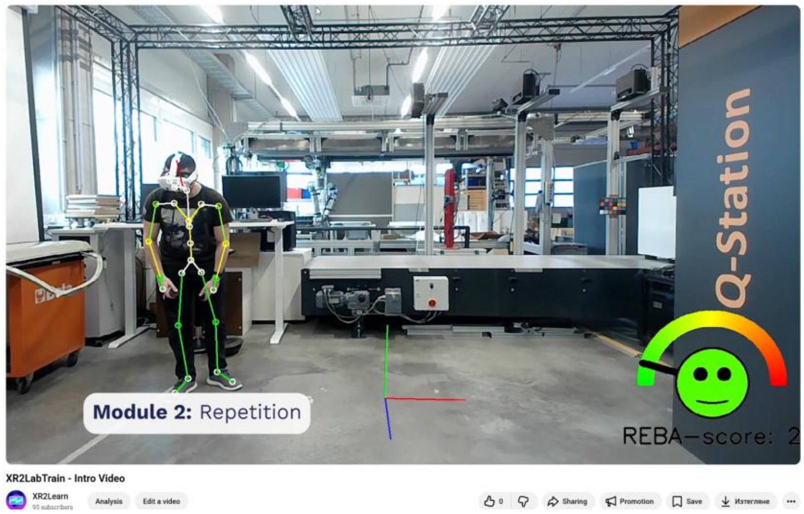

Figure 21: A SCREENSHOT OF THE XR2LABTRAIN INTRODUCTORY VIDEO

The unique value proposition of XR2LabTrain lies in its ability to bridge the gap between immersive digital training and real-world industrial quality control through a comprehensive, human-centric XR ecosystem. The platform combines VR technologies for scalable and safe workforce training with Spatial Augmented Reality systems that provide real-time assistance during physical inspection and production tasks.

A key differentiator of the project is its closed-loop data pipeline, where newly detected defects and operational data captured on the shop floor are continuously fed back into the XR training environment. This ensures that training content remains aligned with evolving production conditions and real industrial challenges.

The platform also integrates adaptive and personalized learning mechanisms through a Learner Proficiency Enabler (LPE), which analyzes behavioral metrics such as decision-making patterns, accuracy, and error rates to dynamically adjust training difficulty and provide targeted support. In parallel, the system incorporates automated ergonomic assessment capabilities using optical tracking and REBA (Rapid Entire Body Assessment) scoring to monitor posture and movement quality during inspection procedures, helping reduce long-term ergonomic risks for workers.

Another important aspect of the solution is its ability to reduce cognitive load and improve operational efficiency through projection-based interfaces and immersive guidance mechanisms directly integrated into physical workflows. By serving both as a workforce training platform and an operational quality-control support tool, XR2LabTrain demonstrates strong commercial potential and applicability across multiple stages of industrial production and workforce development.

4.5. XRTwinScape

Figure 22: XRTwinScape logo

XRTwinScape is an XR-based immersive training project designed to address major challenges in industrial and vocational education, including limited access to specialized laboratories, varying learner skill levels, and low engagement in traditional online learning. The project enables learners to explore realistic virtual training environments and digital twins before participating in physical hands-on sessions, helping improve preparedness, engagement, and knowledge retention.

The platform combines digital twin technologies, Gaussian Splatting-based 3D reconstruction, and adaptive XR learning experiences to create accessible and cost-effective immersive training environments. Unlike traditional solutions requiring specialized hardware, XRTwinScape uses standard smartphone cameras and machine learning techniques to generate navigable 3D scenes, significantly reducing development costs and complexity.

XRTwinScape also integrates the XR2Learn **Personalization Enable**r to monitor learner interactions and dynamically adapt training difficulty based on individual performance and engagement. Training scenarios are designed using pedagogical frameworks such as ASSURE, TPACK, and Bloom's Taxonomy to ensure strong alignment between educational objectives and immersive learning experiences.

Technically, the project developed a cloud-native software ecosystem including tools for environment digitization, lesson management, annotation editing, and XR-based immersive training delivery through browsers and XR headsets. The consortium combined expertise in XR technologies, instructional design, and 3D reconstruction to deliver a scalable and learner-centered XR training platform applicable to manufacturing, vocational education, and other sectors requiring immersive digital learning environments.

During the Pilot Specification phase, the consortium defined the architecture of its immersive XR training platform focused on digital twins, adaptive learning, and vocational education. The project adapted XR2Learn technologies and pedagogical frameworks to develop scalable and cost-effective immersive training environments based on Gaussian Splatting and smartphone-generated 3D reconstructions. Following a successful evaluation, XRTwinScape advanced to the Pilot Execution phase as one of the top eight projects. During this phase, the consortium developed and validated its cloud-native XR ecosystem, including digital twin creation pipelines, annotation tools, immersive lesson delivery systems, and adaptive training functionalities integrated with XR2Learn personalization technologies. XRTwinScape successfully completed its XR2Learn journey during the Pilot Execution phase, demonstrating strong potential for scalable XR-based vocational and industrial training applications.

4.5.1. Technical results and utilization of XR2Learn ecosystem

The technical results of the XRTwinScape project included the development of a cloud-native software ecosystem and a dedicated lesson file format designed for immersive XR-based training. At the core of the platform is a digital twin creation pipeline that converts standard smartphone video footage into high-quality navigable 3D environments using Gaussian Splatting techniques, significantly reducing the need for specialized hardware and manual 3D reconstruction processes.

The project developed several interconnected software components, including a management dashboard for lesson creation, media management, and monitoring of digital twin processing workflows, as well as an annotation editor that enables trainers to enrich virtual environments with spatially anchored multimedia content such as text, images, audio, and video. An XR Player application was also developed to deliver immersive training experiences through VR headsets, such as Meta Quest 3, and web browsers, guiding learners through structured activities and training scenarios.

A key technical innovation was the introduction of the XRTwinScape Lesson (.tsl) file format, designed to combine digital twin environments with embedded multimedia learning content and annotations. The format supports Gaussian Splatting models, JSON-based annotation structures, and integrated multimedia assets, enabling the creation of richly contextualized immersive learning experiences.

The platform additionally integrated the XR2Learn Personalization Enabler, allowing the system to stream trainee interaction data to AI-based back-end services that dynamically adapt activity difficulty and learning pathways based on real-time learner performance.

From a performance perspective, the system was optimized for efficient scene reconstruction and immersive visualization. High-quality digital twins could be generated from fewer than 600 video frames within a processing time of under four hours, while the XR environment was designed to support smooth real-time performance on standard high-performance hardware configurations, including NVIDIA RTX GPUs and VR-ready systems.

4.5.2. Dissemination and UVP

The XRTwinScape project implemented a multi-channel dissemination strategy aimed at ensuring broad visibility, stakeholder engagement, and long-term adoption of its results. Dissemination activities included the establishment of a dedicated **GitHub repository** for sharing technical documentation and software components, as well as regular communication through the project website, LinkedIn, X, and the XR2Learn forum.

The consortium also organized and participated in webinars, workshops, and major trade fairs and educational events, including Fiera Didacta and JobOrienta, while additionally supporting the ITADINFO conference in October 2025. Academic dissemination activities included plans for publishing project findings in high-impact technical and pedagogical venues such as IEEE VR.

To strengthen educational integration and long-term sustainability, the project worked towards integrating the XRTwinScape platform into the curricula of the University of Salerno. In parallel, the consortium developed the concept of the “TwinScape World” publishing platform, designed to ensure the continued accessibility, dissemination, and reuse of immersive training materials beyond the project’s official duration.

XRTwinScape has also developed a project introductory video and a demo video published on the XR2Learn YouTube channel.

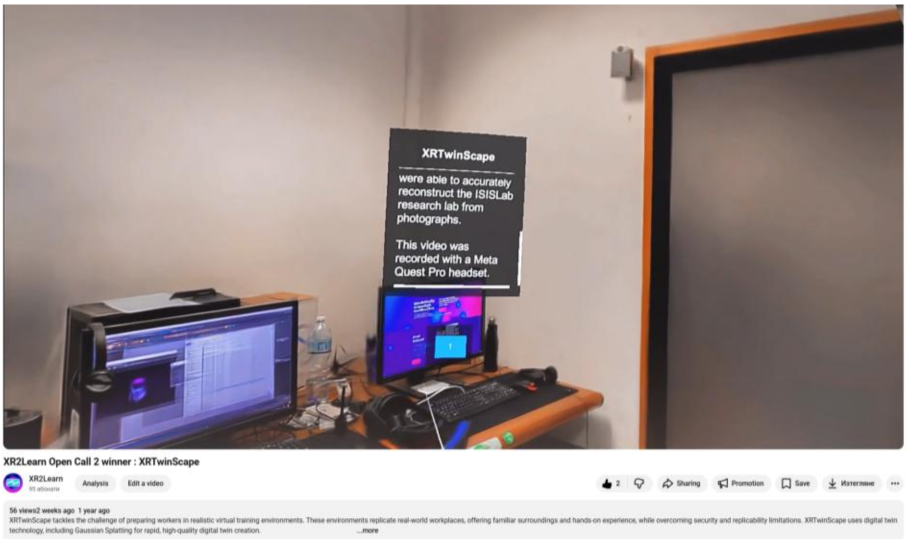

Figure 23: A SCREENSHOT OF THE XRTWINSCAPE DEMO VIDEO

The unique value proposition of XRTwinScape lies in its ability to deliver a scalable, cost-effective, and highly immersive XR training solution that addresses major logistical and pedagogical barriers in industrial and vocational education. Unlike many existing digital twin solutions that rely on specialized LiDAR equipment or proprietary cameras, XRTwinScape generates photorealistic and navigable 3D training environments using only standard smartphone video and Gaussian Splatting technologies, significantly reducing hardware costs and content creation complexity.

A key differentiator of the platform is its rapid and cloud-native processing pipeline, which eliminates the need for manual 3D modelling and mesh editing while enabling high-quality digital twins to be generated within a few hours. The platform also integrates the XR2Learn Personalization Enabler, allowing training activities to dynamically adapt in real time according to learner performance, interaction patterns, and engagement levels.

Unlike general-purpose spatial mapping solutions, XRTwinScape was specifically designed for immersive skill development and vocational learning. The platform includes dedicated annotation and lesson-authoring tools that enable trainers to embed multimodal learning content, such as text, images, audio, and video, directly into virtual environments to support contextualized and scenario-based learning experiences.

Another important aspect of the platform is its scalability and accessibility. Through cloud-based delivery mechanisms, XR training sessions can be simultaneously accessed by large numbers of remote users via web browsers or VR headsets. Combined with its tiered Software-as-a-Service (SaaS) model, including both open-source and premium versions, XRTwinScape lowers the barriers to adoption for vocational schools, SMEs, and training providers seeking affordable access to advanced XR-based learning technologies.

4.6. XPOTLESS

4.6.1. Technical results and utilization of XR2Learn ecosystem

Figure 24: XPOTLESS logo

The XPOTLESS project (**XR exPerience fOr Training cLeaning and disinfEction Safety practiceS in the agrifood sector**) is a second open call winner based in Spain, led by ENCLAVE in collaboration with ASINCAR. It addresses the critical need for modernized training in industrial cleaning, a sector often plagued by high risks, repetitive tasks, and static, non-personalized training methods that lead to safety incidents.

XPOTLESS is built on a modular architecture using open tools such as Unity, Docker, and OpenXR to ensure scalability and cross-platform compatibility. The project focuses on the following complementary phases:

- **Mobile 360° Theoretical Module:** A mobile application developed in Unity that utilizes an XR Origin system to deliver immersive 360 grad instructional videos. This allows users to acquire theoretical knowledge remotely at their own pace without needing physical presence in a facility. The app includes a visual course creation tool for instructors to configure learning itineraries and interactive question prefabs with multilingual support (Spanish and English).

- **Immersive VR/MR Practical Module:** A practical training environment where users practice high-risk procedures interactively. A primary technical achievement is the development of an innovative gesture capture component. This enabler allows users to record and store full-hand gestures in real-time directly from an XR headset with a single button press, eliminating the need for manual, joint-by-joint bone configuration.

In terms of utilization of the XR2Learn ecosystem, XPOTLESS has integrated XR2Learn Enablers 2 through 6, which cover emotion recognition, multimodal classification, and personalized difficulty recommendations. The system specifically extends these enablers by implementing an audio detection functionality to capture user voice data (tone and rhythm) for emotional inference pipelines via Redis.

The XPOTLESS project successfully advanced to the pilot execution phase (M7–M10) of XR2Learn's Open Call 2 with a total score 7.6/10, evolving from a preparatory infrastructure into a mature, validated affective computing and personalization solution. This phase focused on large-scale validation and the technical integration of an AI-based emotion recognition pipeline to deliver a data-driven, adaptive training system.

The pilot methodology and validation of project's outputs was executed by a large-scale pilot involving approximately 80 participants to validate the stability and usability of its software ecosystem. The hardware setup utilized Meta Quest 3 headsets, leveraging their Mixed Reality and hand-tracking capabilities to lower the entry barrier for non-technical users. Testing was structured around two complementary applications:

- **Mobile 360° Learning Module:** A theoretical component where users visualized hygiene procedures step-by-step and completed interactive quizzes to assess knowledge retention.
- **Immersive VR/MR Training Module:** A practical environment featuring three specific scenarios: PPE Placement, Dry Cleaning, and Detergent Cleaning and Disinfection.

A critical milestone of this phase was the successful integration of a hybrid architecture for emotion detection. Because standalone headsets have processing constraints, the project developed a PC-based emotion analysis application. This application captures user audio during VR sessions, extracts emotional states (such as engagement, boredom, or frustration), and transmits this data to Azure PlayFab.

The VR/MR application then consumes this affective data to dynamically adjust the difficulty level of subsequent training exercises. This ensures an optimal balance between challenge and skill, directly aligning with the Theory of Flow and XR2Learn's affect-aware learning framework.

The quantitative and qualitative results from the execution phase of XPOTLESS project confirmed high levels of user acceptance and learning impact, as participants reported an extremely strong endorsement of XR training. Trainees specifically noted the system's realism, with the agrifood sector providing an average score of 4.3 out of 5, and highlighted the safety benefits of practicing high-risk protocols without real-world exposure to chemical hazards.

Furthermore, knowledge retention was significantly improved, with most users reporting they improved more quickly through XPOTLESS than through traditional training. They cited immediate feedback and the total absence of "dead time" usually spent waiting for materials as key learning accelerators. Finally, the pilot successfully demonstrated both operational and environmental benefits, proving that shifting initial training phases to VR reduces the consumption of water, detergents, and PPE, which ultimately contributes to a lower carbon footprint in alignment with EU sustainability goals.

By the end of the phase, XPOTLESS was recognized as a sector-agnostic framework with strong potential for adoption in manufacturing, healthcare, and education. The project team further integrated into the MANTRA Community as leaders and successfully received peer-review approval for its EIT Manufacturing Academy courses.

Based on the project's technical specification and pilot validation reports, the XPOTLESS team received critical technical support from the XR2Learn consortium to transition from a standard training application to a fully integrated affect-aware system. This intensive support period focused on the implementation of the personalisation pipeline and the effective utilization of XR2Learn enablers. The support granted support in the following concrete technical areas:

Functionality of the Personalisation Pipeline Modules

The consortium guided the XPOTLESS team through a sequential workflow designed to create an affect-aware feedback loop between user behavior and training difficulty:

- **Audio Emotion Model Training:** Instructions were provided on using the XR2Learn CLI and Personalization Training Tools to fine-tune the Wav2Vec2 encoder using GPU acceleration and the RAVDESS dataset.
- **Emotion Inference:** The team was supported in deploying an inference pipeline that analyzes recorded user audio to generate numerical emotion probabilities and identify dominant emotional states.
- **Mapping and Abstraction:** Guidance was given on implementing a decoding layer to aggregate raw audio emotions into high-level affective states required by the personalisation logic: Boredom, Engagement, and Frustration.
- **Difficulty Recommendation:** The consortium assisted in configuring the Personalization Tool to consume these emotional states alongside contextual metadata - such as user skill level and current exercise difficulty - to compute an optimized challenge level for the next session based on the Theory of Flow.

Setting up the Emotion Recognition Docker

To overcome the hardware constraints of standalone VR headsets, the consortium supported the setup of a hybrid system architecture using Docker containers:

- **System Orchestration:** The XPOTLESS desktop application was configured to act as a control layer, coordinating the emotion analysis pipeline deployed within Docker.
- **Messaging Bus:** Support included setting up a Redis connection within a Docker container to serve as a low-latency Pub/Sub messaging bus between the XPOTLESS application and the XR2Learn Personalization Tool.
- **Inference Tools Deployment:** The external pipeline for emotional inference, based on XR2Learn Inference Tools, was successfully dockerized to process audio recordings and return prediction outputs in near real-time.

Connecting Sensors and Data to the Personalisation Module

The team received guidance on integrating real-time data collection managers into the Unity environment to feed the personalisation engine:

- **Audio Capture Integration:** Using the data-collection-module-steamer as a base, the team was supported in implementing a custom AudioManager to record audio via the device's microphone, convert it to .wav format, and send it through the Redis flow.
- **Headset and Modality Fusion:** Support was provided for future-proofing the system to include VR headset sensor data (position, rotation, and acceleration). The consortium demonstrated how these signals could be integrated using the Multimodal Fusion tool from the Inference Tools repository to enhance emotional state detection.
- **Synchronization via Cloud:** To bridge the gap between the desktop personalisation infrastructure and the standalone VR application, the team was guided in using Azure PlayFab as an indirect synchronization mechanism to store and retrieve final difficulty recommendations.

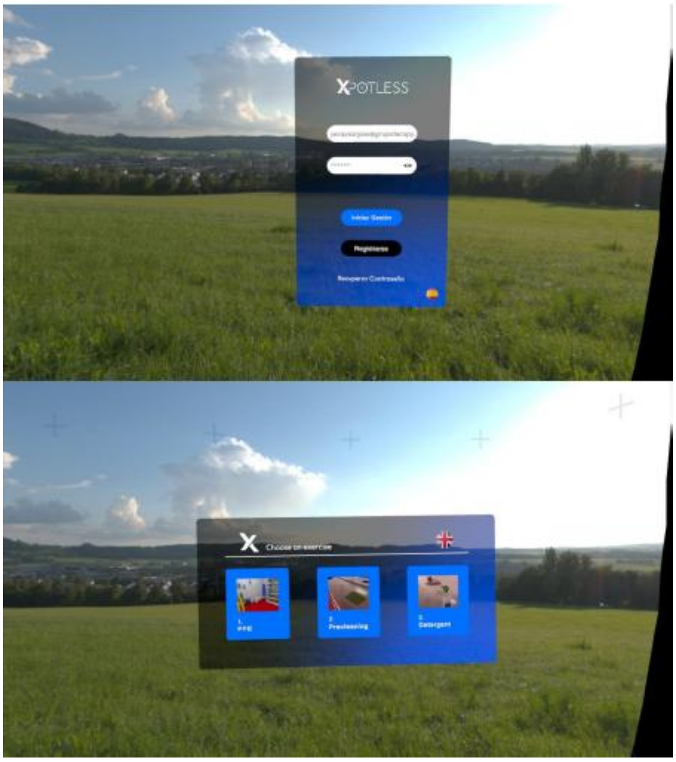

Figure 25: XPOTLESS VR/MR APPLICATION

4.6.2. Dissemination and UVP

The dissemination strategy and Unique Value Proposition of the XPOTLESS project focus on establishing a scalable, emotionally intelligent training ecosystem that bridges the gap between theoretical knowledge and high-risk industrial practice.

Dissemination efforts were designed to showcase the project's practical utility to industrial stakeholders, educational institutions, and the broader XR2Learn community in the following main directions:

- **Industry Events:** The project was showcased at ALIMENCUENTROS, an event organized at ASINCAR facilities to demonstrate agrifood innovations to students and regional stakeholders.
- **Marketplace Contributions:** To foster ecosystem growth, the project prepared all sector-specific 3D models (such as industrial equipment and cleaning tools) and the custom gesture capture enabler for publication on the official XR2Learn Marketplace for third-party reuse.
- **Educational Outreach:** The XPOTLESS team joined the MANTRA Community as leaders and successfully had its training paths peer-reviewed and approved by the EIT Manufacturing Academy.
- **Digital Presence:** The project utilized social media, including LinkedIn and Instagram, to share dedicated videos demonstrating the system to a broader audience.

The Unique Value Proposition of XPOTLESS is rooted in its holistic, trainer-centric, and affect-aware approach to industrial hygiene training, beginning with its ability to provide effective personalization without the need for intrusive hardware. By utilizing a PC-based audio analysis module to detect emotional states such as boredom, engagement, and frustration from voice data, the system dynamically adjusts training difficulty in real-time to maintain an optimal balance between challenge and learner skill. To further support the user experience, the platform features real-time immersion control that allows learners to switch instantly between VR and MR through a personalized hand gesture. This functionality significantly reduces technological hesitancy by enabling users to remain aware of their physical surroundings or view their instructor whenever necessary.

The solution also ensures a low barrier to adoption for trainers by providing a visual course creation tool that allows instructors to configure modular 360° learning itineraries and manage sessions through simple numeric identifiers, removing the requirement for advanced XR or AI development expertise. In terms of hybrid learning efficiency, the project targets a 40% reduction in training session time by strategically combining remote, self-paced mobile instruction with immersive hands-on practice. Finally, the project promotes sustainable and safe practices by eliminating real-world exposure to hazardous chemicals and reducing the consumption of water and detergents during the initial training phases, thereby contributing to broader environmental goals.

The XPOTLESS intro video and a demo video are accessible on XR2Learn's YouTube channel.

4.7. RTXRoom

4.7.1. Technical results and utilization of XR2Learn ecosystem

Figure 26: RTXRoom logo

RTXRoom (Remote Training XR Room) is an adaptive and collaborative XR platform designed by the Greek SME D-Cube to revolutionize industrial training, specifically for aluminium frame assembly. Piloted at the Architectural Aluminium Academy (AAA), the project focuses on addressing workforce upskilling challenges, reducing high training costs, and overcoming the limitations of physical supervision in global construction projects.

RTXRoom is built upon a modular, Unity-based architecture developed for the Microsoft HoloLens 2. It leverages a user-centered design to provide a highly interactive training environment that transitions from individual instruction to multi-user collaborative scenarios. Key technical components of the solution include:

- **Authoring and Narrative Tools:** The system utilizes an in-house "Narrative Editor" that allows experts to generate dynamic assembly instructions from 3D models. At runtime, the application asynchronously loads 3D models, holographic animations, and supplemental media (PDFs, videos, audio).
- **Immersive Interface (MRTK3):** Using the Microsoft Mixed Reality Toolkit 3, RTXRoom offers intuitive hand-gesture recognition, voice commands, and gaze

interaction. A persistent step-control interface and animation slider allow trainees to scrub through assembly sequences to control the pace of their own learning.

- **Remote Assistance and Live Streaming:** A dedicated Streaming Editor allows remote instructors to view a trainee's perspective in real-time, providing live feedback, step correction, and annotations with minimal latency.
- **Multi-user Collaboration:** The platform synchronizes 3D training scenarios across multiple HoloLens devices, enabling synchronized multi-user sessions where participants can jointly manipulate virtual parts and practice peer-to-peer mentoring.

The project achieves real-time personalization by tightly integrating XR2Learn's Personalization Enablers 2 through 6, creating a closed-loop system that continuously adapts the training journey to the trainee's emotional and cognitive state. This process begins with data collection and processing through Enablers 2-4 (tools for building emotion representations, for using pre-trained emotion representations and tools for building emotion classifiers), where RTXRoom ports XR2Learn's standard data collection system to the HoloLens 2 to capture high-frequency time-series data from head and hand tracking. This information is then passed to Enabler 5 for affective inference, where Dockerized AI inference services utilize a CNN1D encoder to perform real-time classification, detecting emotional states such as being engaged, bored, or frustrated.

Finally, dynamic personalization is realized through the Personalization Enabler via a dedicated Redis Pub/Sub module in Unity that subscribes to the inference tool's output. Based on the detected emotional state, the system automatically suggests adjustments to critical aspects of the experience, such as task difficulty, instructional pacing, or the level of expert guidance provided to the user. The pilot aims for a technical maturity level of TRL 8 and a manufacturing readiness of MRL 5, ensuring it is validated for real-world adoption in industrial production environments.

The RTXRoom project successfully advanced to the Pilot Execution Phase of the XR2Learn Open Call 2, which took place from project months M7 to M10. This phase focused on the large-scale deployment and rigorous validation of the XR training solution within the real-world operational environment of the Architectural Aluminium Academy (AAA). Key aspects of RTXRoom's continuation into this phase include:

- **Pilot Objectives and Setup**

The primary goal of Phase II was to validate the technical and functional aspects of the application under realistic training conditions. The project utilized Meta Quest 3 (through its predecessor) and HoloLens 2 headsets to deliver immersive training scenarios to actual end users, including trainees and industry professionals.

- **Large-Scale Participation and Demographics**

The Phase II pilot engaged a total of 60 participants distributed across seven sessions. The cohort represented a diverse range of roles:

    - Trainees (25) and Technicians (13): The primary users performing hands-on assembly tasks.

- Instructors/Trainers (4): Validating usability and providing expert guidance.
- Other Roles: Supervisors (6), Managers (4), Developers (3), and Academy Associates (5). Efforts were made to promote gender balance, resulting in a sample of 17 women (28.3%) and 43 men (71.7%), a distribution that reflects the structural constraints of the predominantly male-dominated aluminium sector in Greece.

- **Validation of Educational Scenarios**

The pilot successfully executed two core educational scenarios:

- Scenario I (Individual Training): Focused on self-paced procedural learning and tool usage for aluminium frame assembly.

Scenario II (Collaborative Training): Extended the system to support multi-user interactions and team-based problem solving within a shared XR environment.

- **Technical and Human-Centered Results**

The execution phase confirmed high levels of performance and acceptance:

- User Satisfaction: RTXRoom achieved an overall satisfaction rate exceeding 90%, with 91% of users finding the system easy to use.
- Training Effectiveness: The pilot reached a targeted 85% reduction in training errors, validated through self-reports and instructor observations.
- Technological Maturity: By project month 10, the project justified reaching TRL 8 (system validated in an operational environment) and MRL 5 (repeatable deployment and stable integration of hardware/software).

The successful completion of this phase provided a solid foundation for the subsequent Growth and Exploitation phase, proving that the modular architecture of RTXRoom is ready for wider industrial uptake.

Figure 27: MULTI-USER TRAINING SESSION AT THE AAA PILOT SITE USING HOLOLENS 2 DEVICES BY RTXROOM

During the initial three-month Pilot Specification Phase, RTXRoom was challenged to lay the technical and business foundations for its application. The team focused on mapping out individual 3D guidance systems and defining precise KPIs. A key component of this phase was delivering a comprehensive business plan alongside Deliverable D1 (Detailed XR Pilot Specification), which was presented to a panel of external experts. RTXRoom successfully passed this evaluation stage, proving its technical excellence and industrial relevance to secure a spot as one of the top eight projects allowed to advance in the program.

In the Pilot Execution Phase, spanning months four to ten, the team transitioned the prototype into a large-scale real-world testing environment. Technologically, the project integrated XR2Learn's Personalization Enablers, porting a data collection system to the HoloLens 2 to capture head and hand tracking metrics. This high-frequency data was processed via Dockerized AI inference services utilizing a CNN1D encoder to detect real-time user emotional states such as engagement, boredom, or frustration.

Using a dedicated Redis Pub/Sub module in Unity, the system automatically adjusted task difficulty and expert guidance to keep the learner in an optimal learning zone. Furthermore, the implementation of a Streaming Editor allowed remote experts to provide live feedback from any geographic location, bridging the gap between expert and novice while minimizing travel costs. The pilot successfully validated that this structured XR format accelerated upskilling and targeted a massive reduction in training onboarding errors by up to 85%. Passing both the mid-phase (M6) and end-phase (M10) execution reviews, RTXRoom achieved a Technology Readiness Level of TRL 8, ranking among the top eight sub-projects selected to advance to the final phase.

4.7.2. Dissemination and UVP

The RTXRoom project established an extensive dissemination strategy and Unique Value Proposition focused on modernizing industrial training through adaptive, collaborative, and emotionally responsive XR technologies. Dissemination efforts were aimed at fostering transparency, scalability, and engagement with the broader industrial and educational communities. Main directions in this aspect were:

- Open Community Contributions: D-Cube and the Architectural Aluminium Academy (AAA) contributed a collection of handcrafted 3D industrial tools, such as electric drills, to the XR2Learn Marketplace as free, reusable learning resources for other XR developers.
- Familiarization Course: An open RTXRoom Familiarization Course was published on the EIT Manufacturing Academy platform. This structured learning path introduces users to HoloLens 2 setup, workspace navigation, and how to execute collaborative XR-based training sessions.
- Flagship Strategic Positioning: RTXRoom is promoted as a flagship innovation in AAA's digital transformation strategy, using pilot visuals and testimonials from real training sessions to demonstrate its practical value to partner networks.
- Targeted Promotion: Commercial exploitation is supported through success stories, infographics, and newsletters, as well as one-to-one presentations for potential customers, partners, and investors.

RTXRoom distinguishes itself from traditional training and generic products by offering a comprehensive, data-driven ecosystem. Unlike single-user tools, it provides an end-to-end collaborative platform that integrates individual 3D guidance, multi-user synchronized sessions, and real-time remote expert assistance. This system features emotion-aware adaptive training by utilizing XR2Learn Personalization Enablers to analyze user audio and body-tracking data. By detecting emotional states such as boredom or frustration, the platform can automatically adjust task difficulty to maintain the learner in an optimal "Flow" zone.

The RTXRoom platform further acts as an expert-novice bridge through its integrated Streaming Editor, which allows experts to provide live feedback and step correction from any geographic location. This capability significantly reduces training expenses, eliminating expert travel costs estimated at approximately €650 per day. RTXRoom also enables accelerated and measurable upskilling, targeting a reduction in training errors by up to 85%. Because these sessions follow a structured XR format, training delivery remains uniform and measurable, which increases the overall credibility of vocational certifications. Finally, the project aligns with Industry 5.0 and sustainability goals by shifting training to virtual environments. This approach minimizes production downtime and eliminates the need for physical materials and travel during initial learning phases, directly supporting EU Green Deal objectives.

The RTXRoom's project intro video and a demo video is available on XR2Learn's YouTube channel.

4.8. EcoDrive XR

4.8.1. Technical results and utilization of XR2Learn ecosystem

ECODRIVE XR

Figure 28: EcoDrive XR logo

The EcoDrive XR project is a holographic XR training initiative developed by MATSUKO in collaboration with the Secondary Vocational School of Industrial Technologies in Košice-Šaca, Slovakia. The solution modernizes vocational education for the electric vehicle industry by combining immersive XR environments with lifelike holographic teachers to address the growing skills gap in green manufacturing.

The technical foundation of EcoDrive XR relies on the integration of MATSUKO's patented holographic technology with the XR2Learn technical framework.

- Holographic Presence: Unlike traditional 3D avatars, the platform uses a patented AI-powered reconstruction method to create photorealistic 3D holograms of real teachers from a single 2D camera input. This technology preserves over 80% of human communication cues, including facial expressions, eye contact, and body language, providing emotional presence far beyond standard digital twins.
- Modular Learning Journey: The application is structured into seven interconnected modules delivered via Meta Quest headsets:
    - Introduction & Onboarding: Cinematic transition from Earth to the classroom to establish emotional tone.

  - Safety Protocols: Interactive demonstrations of PPE and emergency protocols in a virtual EV factory.
  - Battery Overview & Production: Deep dive into lithium-ion structures where students manipulate components to understand performance and sustainability trade-offs.
  - Car Assembly: Step-by-step virtual assembly of a life-size Volvo EV, including robotic assembly and quality control checks.
  - Sustainable Materials & Environmental Impact: Exploration of eco-friendly materials and lifecycle visualizations from extraction to recycling.
  - Final Quiz & Feedback: Gaze-based knowledge reinforcement after every module.

EcoDrive XR serves as both a consumer and a contributor within the XR2Learn ecosystem, utilizing five core enablers to drive its adaptive training capabilities.

- XR2Learn Enabler 1 (Interact): Integrated as the technological backbone to enable physics-true manipulation of objects and cables. This allows students to "learn by doing" - grabbing connectors and car parts in a safe virtual environment - transforming the app from an observational tool into an experiential training platform.
- Personalization & Emotion Recognition (Enablers 2-5): The system utilizes Enabler 5 for sophisticated in-session emotion classification based on body-tracking data (head and hand movements). This data, combined with Enablers 2-4, allows for iterative improvements of the evaluation model and real-time personalization, such as adjusting training speed or triggering teacher alerts based on student engagement.
- EcoDrive XR Contributions: The project provides two new enablers to the XR2Learn platform:
  - Holographic Teacher API: A Unity plugin that simplifies the integration of MATSUKO's life-sized holographic instructors into any XR application.
  - 3D Object Manipulation Enabler: A user-friendly module that allows learners to grab, rotate, and combine virtual components with minimal technical overhead.

The initial pilot execution of EcoDrive XR successfully validated the technical feasibility and pedagogical value of the application within real educational environments involving a total of 100 students in Slovakia. Comparative testing conducted during these sessions demonstrated that students trained with the EcoDrive XR application achieved learning outcomes approximately 43% higher than those trained through traditional classroom instruction when covering identical educational content.

Beyond improved knowledge retention, the solution achieved very high levels of learner satisfaction, with students reporting average scores above 4.5/5 across dimensions of usability, engagement, and overall learning experience. The vast majority of participants - most of whom were first-time XR users - found the application intuitive and stated that they preferred the XR format over regular teaching methods. Based on this successful deployment in operational classroom settings with real end users and stable system performance, the project has reached TRL 7, representing a demonstrated system prototype in a relevant environment. Moving forward, the project is targeting TRL 8, with a defined roadmap for full deployment readiness at the Volvo training center and scaling across national and international educational networks.

Figure 29: CREATING A NEW SIMULATION WITHIN THE ECODRIVE XR ECOSYSTEM

Following the successful completion of the Pilot Specification Phase, the EcoDrive XR project advanced into large-scale pilot execution within the XR2Learn OC2 framework, focusing on validating its holographic training solution under real-world conditions. This transition involved deploying the application at two complementary sites in Slovakia: the Secondary Vocational School of Industrial Technologies in Košice-Šaca, which served as a technically demanding vocational training environment, and the Private High School Dneperská, which allowed for the assessment of inclusivity and accessibility among non-specialized learners.

The EcoDrive XR team successfully advanced to the large-scale Pilot Execution Phase (Phase II) conducted between October 2025 and January 2026 of XR2Learn second acceleration program. This multidisciplinary group of experts - including deep-tech pioneers, vocational instructors, and innovation leads - validated their holographic training solution by engaging 100 student participants across two diverse educational sites in Slovakia.

During this phase, the team implemented a structured learning journey featuring lifelike 3D holographic teachers and integrated the XR2Learn INTERACT enabler to provide hands-on, physics-based simulations for electric vehicle manufacturing. The team's transition into large-scale execution proved highly effective, as comparative experiments demonstrated that their immersive training achieved 43% higher learning outcomes than traditional classroom methods, ultimately reaching TRL 7. Following this successful validation, the team outlined a clear roadmap to scale the project toward full industrial deployment at the Volvo Training Centre.

Throughout this phase, 100 students engaged with modular learning paths - including electric vehicle battery production and vehicle assembly - supported by the integrated INTERACT enabler for hands-on virtual manipulation and holographic teacher guidance. The execution results established a robust evidence base for the project's educational impact, demonstrating that the XR-based training significantly outperformed traditional classroom methods while maintaining high levels of user satisfaction and technical stability. Based on these outcomes, EcoDrive XR successfully reached Technology Readiness Level (TRL) 7, securing its path toward final growth and industry-aligned exploitation.

4.8.2. Dissemination and UVP

Dissemination efforts of the EcoDrive XR team included a major "Innovation in Education" event that brought together regional policymakers and industry leaders to witness live holographic training. To drive adoption, the team released national press statements and published an introductory EcoDrive XR Familiarization Course on the EIT Manufacturing Academy platform. The project further supports the community by offering handcrafted industrial 3D assets through the XR2Learn Marketplace.

The Unique Value Proposition centers on providing human-centered, industry-aligned training that is both emotionally resonant and technically precise. By shortening training cycles by 40-60% and increasing information retention to 85-95%, the platform offers a significant ROI for industrial partners like Volvo and InoBat. Additionally, the inclusion of female holographic role models and a device-agnostic, offline-capable architecture makes EcoDrive XR a highly scalable and inclusive tool for bridging Europe's green manufacturing skills gap.

The EcoDrive XR project intro video and demo video is available on XR2Learn's YouTube channel.

4.9. XRive

4.9.1 Technical results and utilization of XR2Learn ecosystem

Figure 30: XRive logo

The XRive project, developed by the consortium of ENEBULA BV, AviSense.AI, and InterMediaKT, proposed an innovative EdTech approach aimed at improving driver safety, awareness, and trust in Connected and Automated Vehicles (CAVs) through Extended Reality technologies. The project concept addressed critical road safety challenges related to human error and sensor limitations by designing immersive training environments where drivers could familiarize themselves with Advanced Driver Assistance Systems (ADAS) and Human-Machine Interfaces (HMIs).

During the Pilot Specification Phase, the consortium designed a comprehensive XR platform concept intended to extend vehicle perception capabilities beyond individual sensors. The proposed architecture included an AR rendering notification system capable of providing early warnings about hazardous objects such as potholes, vehicles, and Vulnerable Road Users (VRUs), including objects located outside the driver's direct field of view or partially occluded. The technical specifications also outlined collaborative perception functionalities leveraging vehicle-to-everything (V2X) communication, together with multiple AR visualization formats such as directional arrows, proximity indicators, and transparent object overlays intended to improve situational awareness while minimizing driver distraction.

The project additionally specified rule-based filtering and prioritization mechanisms designed to dynamically adjust AR content according to factors such as vehicle speed and hazard severity. The proposed platform architecture was designed to remain hardware-agnostic and compatible with devices such as Head-Up Displays (HUDs), AR glasses, and flexible LED interfaces.

XRive also defined several planned integrations with XR2Learn technologies and pedagogical approaches. These included affect-aware personalization mechanisms based on eye-tracking and Eye Aspect Ratio (EAR) measurements to monitor driver fatigue and cognitive load, as well as ergonomic personalization features intended to optimize AR content placement according to individual user characteristics. The consortium further designed a structured three-module training curriculum aligned with Bloom's Taxonomy and the TPACK framework, focusing on XR interface evaluation, hazard response, and driving scenarios under adverse weather conditions.

In line with XR2Learn objectives, the project also planned future contributions toward open-source tools and standardization activities related to XR-based automotive training systems. However, these functionalities remained at the specification and design stage, as the project concluded after the Pilot Specification Phase and did not progress to the Pilot Execution Phase for large-scale implementation, real-world validation, or end-user testing.

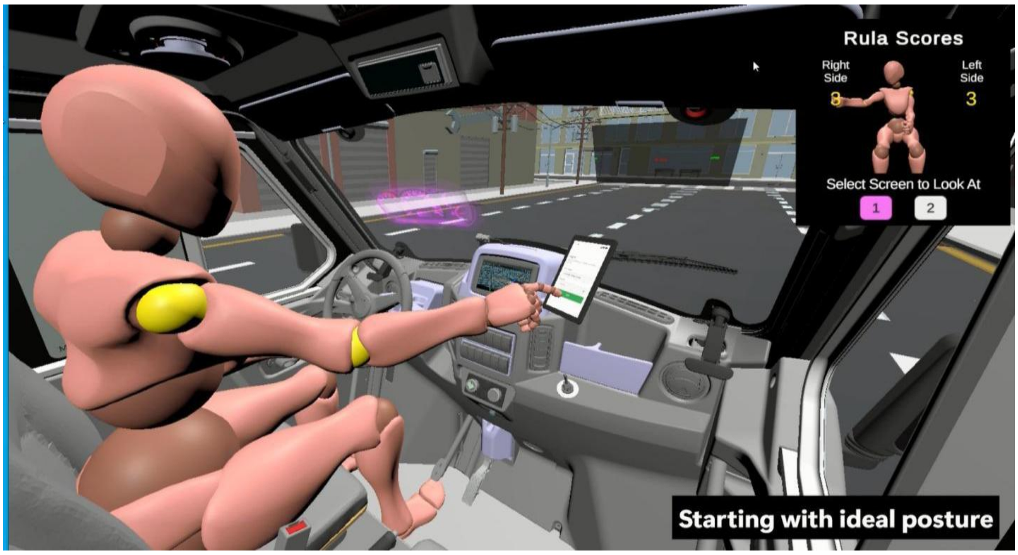

Figure 31: INTERACTION OF USER WITH HMIS AND THE XR PROJECTED INFORMATION ON THE WINDSHIELD THROUGH THE XRIVE TOOL

4.9.2 Dissemination and UVP

During the Pilot Specification Phase, the XRive project defined a human-centered concept for XR-based automotive training and Human-Machine Interface (HMI) validation aimed at supporting the development of Connected and Automated Vehicles (CAVs). The proposed Unique Value Proposition (UVP) focused on creating a user-centered feedback loop that would allow automotive manufacturers and stakeholders to evaluate and refine HMIs using behavioral and cognitive data collected within immersive XR environments.

The project specification outlined several planned functionalities intended to enhance situational awareness and driver trust. These included early visual warnings for occluded hazards such as pedestrians and hidden vehicles, explainable AI (XAI) mechanisms for transparent interaction design, and real-time monitoring of cognitive states such as fatigue and drowsiness through Eye Aspect Ratio (EAR) measurements.

The consortium also proposed ergonomic personalization mechanisms designed to dynamically adapt the positioning of AR content according to individual body dimensions and lines of sight, improving accessibility and usability for diverse user groups.

From an industrial perspective, the project concept aimed to provide automotive Original Equipment Manufacturers (OEMs) with a virtual testing and co-design environment that could reduce reliance on costly physical prototypes while supporting standardized and repeatable XR-based training pathways across different vehicle models and regulatory contexts. However, these functionalities remained at the conceptual and specification level, as the project did not advance beyond the Pilot Specification Phase into implementation and real-world validation activities.

The dissemination strategy proposed by the consortium focused on engaging automotive, XR, and road-safety stakeholders through participation in international industry events such as CES, Automotive World, XR Europe Summit, and the ADAS & Autonomous Vehicle Technology Expo Europe. The project also planned targeted workshops and webinars for Tier 1 suppliers, training providers, and policymakers, together with strategic collaboration activities involving road safety organizations and public authorities.

In line with XR2Learn objectives related to openness and sustainability, the consortium additionally outlined plans for future open-source contributions through platforms such as GitHub and proposed participation in international standardization activities involving ISO, IEEE, and ETSI. These dissemination and exploitation activities were included within the project roadmap but were not fully executed due to the project concluding after the Pilot Specification Phase.

The XRive's project video can be accessed on XR2Learn's YouTube channel.

4.10. XCC

4.10.1. Technical results and utilization of XR2Learn ecosystem

Figure 32: XCC logo

The XR Crowd Control (XCC) project, developed by Mimbus in collaboration with Daher, proposed the development of a monitoring dashboard designed to support trainers facilitating multiplayer Virtual Reality simulation sessions within logistics and warehouse training environments. The project concept was intended to complement the Mimbus Logistics simulator by providing trainers with real-time supervision and analytics capabilities during collaborative XR training scenarios.

During the Pilot Specification Phase, the consortium designed a technical architecture based on the Unity3D engine and a multi-layered networking infrastructure intended to support real-time responsiveness and data synchronization. The proposed system architecture included a monitoring dashboard accessible via tablets or PCs, allowing trainers to observe simulation sessions without participating directly as players. Planned dashboard functionalities included map-based trainee positioning, objective tracking, collaboration monitoring, and screencasting of individual learner perspectives.

The project specification also outlined several networking and synchronization components. These included the use of FMETP Stream for Peer-to-Peer local data transmission, Photon Fusion for multiplayer synchronization, and Photon Voice for low-latency voice communication. In addition, the consortium designed an AI-driven affective analysis framework intended to detect emotional states such as boredom, engagement, and frustration through the analysis of head and hand tracking data combined with physiological measurements obtained from Shimmer3 GSR sensors.

XCC further aligned its proposed training methodology with the XR2Learn Educational Framework by incorporating pedagogical models such as ASSURE and TPACK to support effective technology integration and learner-centered instructional design. The project additionally planned to integrate the XR2Learn inference engine and REDIS-based data management systems to support real-time emotional analysis and adaptive training functionalities.

As part of the Pilot Specification Phase, the consortium conducted semi-structured interviews with trainers from Daher to perform a needs assessment and define project-specific KPIs. The team successfully completed Deliverable D1, including the preparation of a detailed technical specification, dashboard concept, and AI-training approach. However, the project remained at the design and specification stage, as XCC was not selected to advance to the Pilot Execution Phase for implementation, large-scale deployment, or real-world validation activities following the external evaluation process.

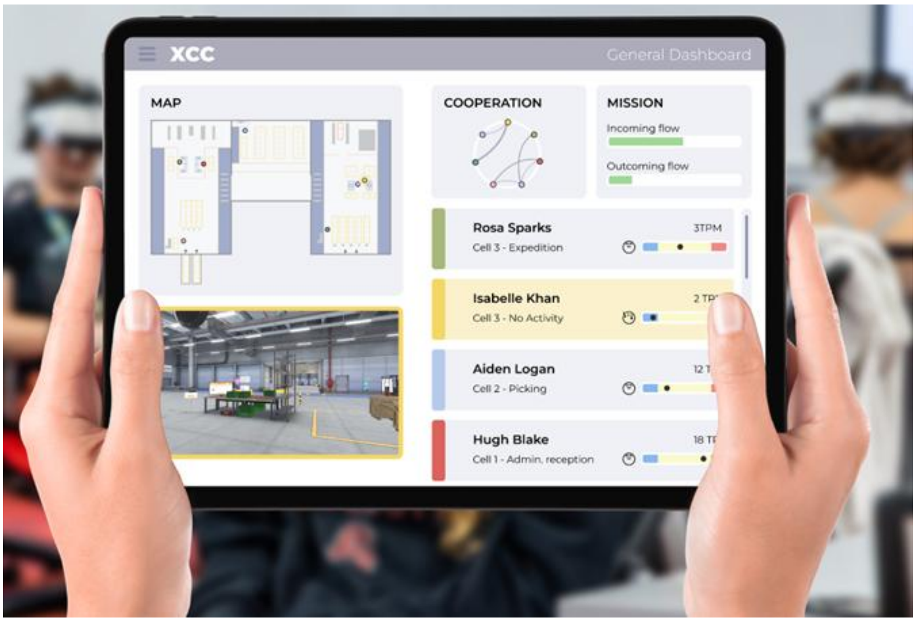

Figure 33: EXAMPLE OF THE XR CROWD CTRL SOFTWARE BY XCC

4.10.2. Dissemination and UVP

During the Pilot Specification Phase, the XCC project defined a dissemination and exploitation strategy centered on the platform's potential as a scalable workforce development and collaborative training support tool within Industry 5.0 environments. Initial validation activities included needs assessments and consultation sessions conducted with trainers and stakeholders at Daher's innovation and training center, which helped shape the proposed dashboard functionalities and pedagogical requirements.

The consortium also outlined plans for future dissemination and ecosystem expansion through the release of a Software Development Kit (SDK) intended to allow external Unity developers to integrate XCC dashboard widgets and monitoring functionalities into their own XR simulators and training platforms. This strategy was designed to support the creation of an extensible and cross-sector collaborative VR training ecosystem applicable to logistics, manufacturing, and other industrial domains.

The proposed Unique Value Proposition (UVP) of XCC focused on transforming the role of trainers from passive observers into active, data-informed facilitators capable of monitoring learner interactions, collaboration patterns, and soft-skill development within immersive XR environments. The project specification included planned functionalities for assessing competencies such as autonomy, communication, teamwork, and conflict management through interaction analytics, collaboration-event tracking, and speech-to-text analysis of professional communication.

Another important aspect of the proposed solution was the integration of “human-in-the-loop” monitoring capabilities aimed at reducing trainer cognitive workload while improving the effectiveness and safety of collaborative VR sessions. However, these functionalities remained at the conceptual and specification stage, as the project concluded after the Pilot Specification Phase and did not proceed to implementation, pilot execution, or large-scale validation activities.

XCC’s project video developed within the acceleration program can be found on XR2Learn’s YouTube channel.

5. CONCLUSIONS

The execution of the second XR2Learn open call has successfully met its primary objective of testing, piloting, and validating the user acceptance of innovative XR applications within real-life educational and industrial settings. By focusing on high-maturity solutions reaching Technology Readiness Levels greater than 7, OC2 has reinforced the ecosystem's capacity to deliver market-ready tools for Industry 5.0.

The implementation of a competitive funnel selection approach allowed the consortium to concentrate resources on the most promising projects, narrowing the field from ten initially selected sub-projects to the final three during the Growth phase. Building on the lessons of the first open call, Open Call 2 prioritized the validation of solutions in operational environments, ensuring that the developed tools were technologically robust and met the actual needs of end-users. Sub-projects effectively utilized the technical framework by integrating existing XR2Learn enablers into their pilot scenarios, which enhanced the overall functionality and modularity of the platform. Based on the finalized outcomes of the Open Call programme documented in the project reports, the educational impact, course metrics, and trainee reach within the XR2Learn ecosystem can be elaborated through the distinct performance of its sub-projects. More than 800 trainees were reached through the piloting of the OC2 projects. There are 62 3D models elaborated by the OC2 projects that are available on the marketplace. Additionally they have contributed 7 software applications, 1 library, 9 MOOCs.

Within the XR2Learn ecosystem 15 courses were created, all of them available on the XR2Learn Platform. 80+ trainees are still enrolled for the different courses as of M41.

The dedicated Growth phase ensured that the final sub-projects developed concrete exploitation plans, participated in key industry networking events, and finalized business strategies to secure long-term viability beyond the initial funding period. The selection of the Top #1 Project, NEONATAL, highlights the programme's success in identifying high-impact solutions that demonstrate superior potential for market uptake and societal benefit. Overall, Open Call 2 has significantly enriched the ecosystem by transitioning innovative XR concepts into validated, user-accepted applications while fostering a community of practice that bridges the gap between developers, educational institutions, and industrial stakeholders.