



Co-funded by
the European Union



Non-Destructive Testing

Deliverable D3.2 - Transnational Virtual Reality Platform for the Practical Part of the Penetrant Testing Examination/Control Course and Living Lab Laboratory Network in the Project Theme

ERASMUS-EDU-2023-PI-FORWARD-LOT2



BIBA



Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.



VRVET

Non-Destructive Testing

1st	30.11.2025	Sundus Fatima (BIBA)	Submitted for internal review
2nd	11.12.2025	(EWF)	Peer Review Process
3rd	12.12.2025	ISIM	Comments from Peer Review addressed
4th	17.12.2025	BIBA	Comments from Peer Review addressed
5th	19.12.2025	IIS	Comments from Peer Review addressed
6th	22.12.2025	CESOL	Comments from Peer Review addressed



INDEX OF THE DOCUMENT

Table of Figures.....	3
Table of Tables.....	3
Executive Summary	4
Introduction.....	4
VR Platform	5
Overview of Platform Architecture.....	5
Technical Components.....	9
Moodle-Based VR Platform Setup.....	14
Implementation of Scenarios (Technical Workflow in Unity).....	18
Integration of Moodle-Based VR Platform with Scenarios	25
Living Lab Network	26
Definition of Living Lab in Project Context.....	29
Network Structure and Partner Roles.....	30
BIBA Living Lab: Central Hub and Technical Development Node.....	30
Partner Living Labs: Local VR Training and Testing Environments	36
Workflow of Interaction between Labs	61
System-Level Workflow and Interaction	62
Conclusion	63



Table of Figures

Figure 1: HTC Vive Focus Vision.....11

Figure 2: Platform Login Interface17

Figure 3: Main Dashboard.....17

Figure 4: Direct VR Headset Access to Moodle Platform18

Figure 5: Unity XRI call back registration for grab, release, and trigger events20

Figure 6: Implementation of collider-driven directional wiping logic.....22

Figure 7: In-scene arrangement of interactable VR tools within the scenarios environment, illustrating the objects controlled by the reset and behaviour management systems (XRGrabInteractable and Physics constraints)23

Figure 8: Dynamic world-space prompt displayed during the active training stage, providing real-time procedural guidance to the trainee24

Figure 9: XR/VR/AR infrastructures available within the Living Lab setup at BIBA, illustrating BIBA’s technical capacity for immersive co-creative development and interactive system validation supporting the VR-VET ecosystem32

Table of Tables

Table 1: Living Lab Network Node Information (BIBA)32

Table 2: Living Lab Network Node Information (CESOL).....36

Table 3: Living Lab Network Node Information (IPUNTO)40

Table 4: Living Lab Network Node Information (Walter Tosto).....44

Table 5: Living Lab Network Node Information (ISIM)50

Table 6: Living Lab Network Node Information (IIS).....54



Executive Summary

This deliverable presents a detailed overview of the current implementation of the VR platform and the distributed Living Labs network. It focuses on the technical structure, operational status, and coordination mechanisms enabling immersive vocational training in Non-Destructive Testing (NDT) across multiple partner institutions. A central focus of this deliverable is the workflow governing the interaction between labs. Scenario builds, initially developed at *BIBA*, are shared and locally tested by partners. This ensures version consistency, deployment traceability, and quality assurance across the distributed system. Integration with the Moodle platform is currently being finalized to enable streamlined content access and training data collection from all participating labs.

The Moodle-based VR platform, hosted at *BIBA*, has been deployed as the centralized digital infrastructure for content distribution and user authentication. It is equipped with role-based access control and structured account provisioning to support secure user access.

The Living Lab network is structured as a transnational infrastructure of local VR labs, each technically aligned with the central node at *BIBA*. Partner institutions are responsible for configuring their local environments in accordance with the reference specifications defined at the central hub.

This deliverable demonstrates the operational setup of the VR platform and the standards-compliant Living Lab network. Together, they form a scalable and interoperable foundation for coordinated scenario deployment, iterative enhancement, and structured knowledge exchange across all partner institutions.

Introduction

The *VR-VET* project aims to establish a technically and pedagogically aligned infrastructure for immersive vocational training in Non-Destructive Testing (NDT) using Virtual Reality (VR) technologies. Central to this is the deployment of a Moodle-



based VR training platform and the development of a transnational Living Lab network that enables distributed scenario deployment, iterative feedback collection, and cross-institutional alignment across partner institutions.

This deliverable presents the development, and operational structure of the implemented system. It outlines the technical specifications of the Moodle-based VR platform, hosted at *BIBA*, which serves as the central node responsible for scenario development, content validation, user management, and data hosting.

A key component of the system is the network of Living Lab nodes established at partner institutions. These labs are equipped with standardised VR hardware, local test environments, and institutional workflows that align with the central development node. Together, they enable testing and delivery of VR training content while ensuring methodological consistency and quality assurance.

The document further describes the workflow of interaction between labs, including the mechanisms through which scenario builds are shared, tested, refined, and deployed. It details how scenario is developed at *BIBA* and disseminated to partners for local validation, followed by feedback integration. This feedback loop ensures system-wide consistency and allows the VR training environment to evolve based on empirical input from all consortium members.

By establishing this synchronised ecosystem comprising both the VR platform and the Living Lab infrastructure, the VR-VET project ensures scalable, flexible, and high-quality delivery of VR-based NDT training, laying the groundwork for broader adoption and sustained educational impact.

VR Platform

Overview of Platform Architecture

The VR platform has been designed and developed as an integrated system that connects immersive Virtual Reality (VR) training with a web-based learning environment. Its structure enables users to perform Non-Destructive Testing (NDT) procedures within a virtual laboratory, while the Moodle platform manages user access, course organization, and the tracking of performance data.

The platform architecture is based on a modular design with three connected layers:



- **VR Training Environment (Unity)** – an interactive 3D environment developed in Unity for the *HTC Vive Focus Vision* headset.
- **Learning Management System (Moodle)** – a structured web-based environment hosting the VR modules as learning courses.
- **Data Exchange Framework (xAPI/LRS)** – a defined connection layer for synchronization between training results in VR and learner records in Moodle.

This structure enables defined separation between immersive learning, content management, and data communication, making the platform flexible and easy to expand.

VR Training Environment

The VR component is developed in *Unity* and deployed for the *HTC Vive Focus Vision* headset. It includes a complete, guided workflow for Penetrant Testing, covering all six procedural stages: cleaning, applying penetrant, removing excess, applying developer, inspection, and evaluation.

The VR training environment is developed in *Unity 2021.3.16f1 LTS* using the *Universal Render Pipeline (URP)* and configured for deployment on the *HTC Vive Focus Vision* headset through the *OpenXR* runtime. The development follows *Unity's XR Interaction Toolkit (XRI)* framework, which provides standardized, cross-device interaction handling.

The environment simulates the full Penetrant Testing workflow based on *Non-Destructive Testing (NDT)* procedures. It comprises six sequential stages:

1. Initial cleaning of the test surface
2. Application of the penetrant
3. Removal of excess penetrant
4. Application of developer
5. Inspection and evaluation
6. Completion and result acknowledgement

Each stage is implemented as a modular scene state controlled by dedicated *C#* scripts that manage object states, trigger events, and user prompts. The training



logic ensures that user progression follows the defined sequence while monitoring interaction accuracy through collider-based triggers and object status validation.

The interaction system is driven by the *XR Interaction Toolkit's Action-Based Controllers*, which support both Teleportation and Continuous Movement through *Unity's TeleportationProvider* and *ActionBasedContinuousMoveProvider*. This allows users to navigate naturally within the virtual laboratory while performing task-specific interactions.

Object manipulation uses the *XRGrabInteractable* component, extended through custom scripts for:

- Grip input mapping using the *OpenXR* controller profile for *HTC Vive*
- Object return-to-origin logic ensures tools automatically reset to their predefined locations after release
- Collider-driven task validation, where interaction zones detect correct cleaning or spraying behaviour
- Particle system activation synchronized with the Trigger input for visual spraying effects

The environment feedback layer combines voice narration, 3D spatial audio, and on-screen UI prompts to guide users step-by-step. All prompts are handled by a centralized *PromptManager* that updates dynamically based on user actions. The *AudioManager* component provides event-based sound playback for actions such as spraying, completing cleaning tasks, or grabbing tools.

At the end of the training session, a summary interface displays user progression data (completion of stages and total time spent) before returning to the main menu. This final state is developed to support later integration with the Moodle platform via *xAPI* statements, allowing session data to be recorded in the *Learning Record Store (LRS)*.

Learning Management System (Moodle)

The *Learning Management System (LMS)* of the VR platform has been setup using Moodle, serving as the central digital environment for managing, delivering, and monitoring virtual reality-based training content. Acting as the organizational core of the VR-VET ecosystem, the Moodle platform connects users, partner institutions, and



the immersive Unity-based VR scenarios within a structured and secure online framework.

The platform is hosted under the *BIBA* domain and configured to support access across all participating institutions. Institutional credentials have been established to ensure secure entry, while role-based permissions for administrators, instructors, and trainees will be implemented to manage user responsibilities and content access according to training and evaluation needs. The interface offers a streamlined navigation structure organized across key functional areas, including:

- Home Page
- Login Page
- Courses Page
- Reports
- Help and Setup
- About VR-VET
- Resources

Each of these sections supports both technical and pedagogical functions — from accessing and launching VR modules to providing help documentation, user guides, and project information.

The Moodle environment hosts the VR Penetrant Testing scenario as a structured course, which integrates supplementary materials, including instructional videos, documentation, and direct links to the VR build (APK) for deployment on headsets. The system architecture has been designed and developed to support the integration of *xAPI (Experience API)* and *Learning Record Store (LRS)* for tracking user activity, performance, and completion data within the VR application. These integrations will enable automatic synchronization of results with Moodle's reporting dashboards, supporting data-driven evaluation and monitoring across the Living Labs network.

Data security and privacy compliance are ensured through *GDPR*-aligned protocols, *HTTPS* encryption, and user consent management. Moodle's built-in logging and analytics features provide transparency, while preparations for future *LTI (Learning Tools Interoperability)* integration will enable *single sign-on (SSO)* and seamless data exchange between Moodle and the VR environment.

Overall, the Moodle-based *LMS functions* as the pedagogical and analytical backbone of the VR-VET ecosystem. It bridges the immersive VR training modules with a robust



online management and evaluation framework, supporting structured learning, user tracking, and institutional coordination across all partners Living Labs.

Data Communication Layer

A data communication structure utilizing the *Experience API (xAPI)* and *Learning Record Store (LRS)* has been defined to connect the VR training data with Moodle. While the full integration will be finalized in the next phase, the current version already records user activity internally in Unity and stores training progression data locally.

The defined *xAPI* model will allow automatic transfer of completion and performance data to Moodle once connected, enabling dashboards and progress reporting for learners and administrators.

Technical Components

The VR platform's technical foundation is composed of a modular VR training environment and a Moodle-based learning management system. The VR component, built in Unity, delivers an immersive simulation for Non-Destructive Testing procedures, while Moodle serves as the organizational backbone for managing user access, courses, and performance tracking.

The system is structured to ensure these technical components remain adaptable and scalable. While the architecture already anticipates integration of *xAPI* and *LRS* for data exchange, the current configuration is prepared to support seamless future connectivity.

Hardware Requirements

The hardware requirements of the VR platform reflect its dual-component architecture:

- Standalone/PC-capable VR training environment
- Moodle-based learning management system accessible through standard devices and VR headsets



To ensure consistent operation across all partner institutions, the selected hardware supports reliable VR performance, stable network access, and compatibility with the project's software stack.

HTC Vive Focus Vision

The VR training component has been developed and validated using the *HTC Vive Focus Vision*, which was selected for its *OpenXR* compatibility, stable controller tracking, and ability to operate in both standalone mode and with PC-based rendering, as needed.

Technical Specifications

- **Type:** Standalone 6DoF Mixed Reality Headset
- **Runtime:** OpenXR-compatible (required for controller mapping, input actions, and XR Interaction Toolkit compatibility)
- **CPU/GPU:** Integrated processing units capable of real-time rendering of interactive Unity content
- **Display:** High-resolution stereoscopic display suitable for precision-dependent NDT training tasks
- **Tracking:** Inside-out 6DoF tracking for both headset and controllers
- **Audio:** Integrated spatial audio with optional external headphones
- **Connectivity:** Wi-Fi 2.4/5 GHz required for accessing Moodle and downloading VR modules
- **Storage:** Minimum 1 GB free space for APK installation
- **Power:** Rechargeable battery supporting a full training session

VR Interaction Compatibility

The device supports all interaction types implemented in the VR scenarios:

- Teleportation
- Continuous movement
- Object manipulation (grabbing, placing, returning to initial position)
- Trigger-based actions (spraying)
- On-screen prompt acknowledgment



Controllers

- Dual 6DoF controllers
- OpenXR Action Profile compatibility
- Required input channels:
 - Trigger (tool activation)
 - Grip (object grabbing)
 - Joystick (movement and teleportation)
 - Haptics (optional use)



Figure 1: HTC Vive Focus Vision [1]

Use of Headset Browser for Moodle Access

In addition to running the immersive training scenarios, the *HTC Vive Focus Vision* headset also serves as an access point to the web-based platform that hosts the training materials, documentation, and downloadable VR scenario files. To support this functionality, the device must be able to operate its integrated browser reliably and maintain a stable wireless connection.



The *HTC Vive Focus Vision* includes a built-in Chromium-based browser, which allows trainees and partner institutions to access the platform directly from within the headset. Through this browser, users can navigate the VR platform interface, view instructional materials, download the VR scenario APK file, and access auxiliary training resources. This ensures that the VR device functions both as the execution environment for the scenarios and as an entry point to the digital learning infrastructure.

Central Platform Hosting Environment (BIBA Node)

As the primary hosting node of the platform, *BIBA* provides the central infrastructure required for maintaining institutional access, storing course materials, and supporting performance-related data exchange.

The *BIBA* server environment includes:

- Server-class machine with multi-core CPU and sufficient RAM for handling concurrent Moodle requests
- SSD-based storage for fast content delivery and reliable course hosting
- Redundant backup mechanisms to ensure data integrity and avoid loss of learning materials
- HTTPS-enabled network configuration supporting encrypted external access
- High-bandwidth internet connection for reliable access via VR headsets and partner institutions

Functional Responsibilities

The central hub at *BIBA* provides:

- Hosting of the Moodle-based VR platform and structured course content
- Management of user accounts, roles, and institutional permissions
- Access to documents, instructions, training files, and downloadable VR APKs
- Provision of secure external access for all partner institutions (Living Labs)

Software Requirements

Unity



The VR training scenarios are developed using *Unity 2021.3.16f1 LTS*, selected for its long-term stability, mature XR support, and compatibility with the software and hardware ecosystem required by the VR platform. The project is configured with the *Universal Render Pipeline (URP)* to optimize rendering performance for the *HTC Vive Focus Vision* headset, providing lightweight shaders, efficient real-time lighting, and reduced overdraw while maintaining visual clarity for precision-dependent NDT tasks.

The project uses *Unity's OpenXR Plugin* as the primary *XR* runtime. All interaction input is implemented through the *XR Interaction Toolkit (XRI)*, using the Action-Based Controller workflow. The *OpenXR* backend ensures correct mapping of the headset and controller input profiles, including trigger, grip, joystick axes, primary button, secondary button, and haptic output channels. The *Unity Input System* defines a custom action map that binds *OpenXR* actions to locomotion (continuous and teleportation), object grab actions, spray activation, UI interactions, and stage progression triggers.

Object interactions in the training scenario are controlled through Unity's built-in *Physics Engine (PhysX)*. Collision layers and interaction volumes are configured to support accurate contact detection for cleaning cloths, spray bottles, and inspection areas. Custom *C#* components extend *XRI* functionality by implementing object return-to-position logic, rotational stabilisation, trigger-driven particle emission, timed stage transitions, and collider-driven task validation.

User guidance within the simulation is handled through *TextMeshPro UI*, world-space canvases, and a centralised *PromptManager* that updates instructions according to the trainee's progression. Spatial audio is implemented using *Unity's AudioSource* and *AudioMixer* components, providing event-driven narration, tool sounds, and feedback cues.

The build configuration targets *Android ARM64*, using *IL2CPP* as the scripting backend and enabling *OpenXR* as the exclusive *XR* runtime. Stereo rendering is set to Single Pass Instanced for performance efficiency.

Additional build parameters include:

- Enabled Vulkan/OpenGLES graphics APIs
- GPU instancing support
- Compressed texture formats for standalone deployment
- Storage permission declarations for optional file access



The final Unity configuration ensures that all rendering, interaction, and workflow components operate consistently within the *OpenXR* runtime on the *HTC Vive Focus Vision*. The architecture maintains a clear separation between locomotion systems, interaction logic, audio/visual guidance, and task-specific scripts, enabling stable execution of each procedural stage in the training workflow. This consolidated setup provides a reliable foundation for delivering immersive NDT scenarios, ensuring predictable performance, modular extensibility, and compatibility with the broader platform infrastructure.

Moodle-Based VR Platform Setup

The Moodle-based VR platform serves as the central digital interface for managing VR training activities across the *VR-VET* Living Lab network. Hosted and maintained by the central hub at *BIBA*, this platform not only enables unified access to validated scenario builds but also supports learner performance tracking, instructor facilitation, and iterative system improvement. It forms a core part of the distributed infrastructure that interconnects all institutional nodes participating in the project.

Hosting Infrastructure and System Configuration

The *VR* Moodle platform is hosted on a dedicated virtual machine located within the secure IT environment of *BIBA*. Implemented to support transnational access and network-wide coordination, the platform is publicly accessible via the project-specific domain: <https://moodle.vrvet.biba.uni-bremen.de>.

This public availability ensures that all partner institutions, trainers, and authorised users can access the platform securely and consistently, regardless of geographic location, without requiring VPNs or restricted institutional networks.

The system is deployed using a robust open-source technology stack:

- **Operating System:** Debian Trixie Linux
- **Web Server:** Apache2
- **Database Backend:** MariaDB



These components are widely supported in academic and enterprise environments, offering high reliability and compatibility with modular learning platforms such as Moodle.

Server Specifications

- **Processor:** 4-core CPU
- **RAM:** 4 GB
- **Storage:** 40 GB SSD
- **Network Access:** Secured institutional LAN with full HTTPS support and unrestricted outbound traffic

This configuration provides a stable performance profile for concurrent usage by trainees and trainers across the *VR-VET* consortium. The 40 GB SSD storage allows for hosting scenario files, training modules, and learner interaction logs. Resource utilisation is actively monitored to ensure sustained performance and availability.

To support operational continuity and data security, automated daily backups are implemented. This ensures that the platform is resilient to data loss and compliant with institutional and project-level data protection requirements.

User Account Structure

The user account system for the Moodle-based VR platform has been structured to support secure, role-based access for trainees, trainers, and administrators across all partner institutions. The platform is accessible publicly via <https://moodle.vrvet.biba.uni-bremen.de> is hosted within *BIBA*'s institutional IT environment and protected under *HTTPS* encryption, ensuring data security and compliant access protocols.

At this stage, administrative accounts have been fully configured at the central node (*BIBA*), enabling core platform setup, scenario integration, and system maintenance. In addition, *BIBA* has established two primary user groups for internal testing and instructional purposes: five teacher accounts (`biba_teacher01` to `biba_teacher05`) and five student accounts (`biba_student01` to `biba_student05`). These accounts are



actively used to validate role-based permissions and simulate learner and instructor workflows during the execution of VR scenarios.

Credential provisioning for partner institutions is currently in progress. Each institution will be assigned a distinct set of credentials, mapped to predefined user roles (e.g., student/trainee, trainer), ensuring controlled access to role-specific features within the Moodle platform. Account creation is managed through Moodle's secure user management system, following standard provisioning protocols. This setup guarantees that all users interact with content and data relevant to their role and institutional context, while maintaining a consistent structure across the transnational training network.

VR Platform Interface and Content Structure

The Moodle-based VR platform has been implemented with an interface tailored to the pedagogical and operational goals of the *VR-VET* project. The design adopts a clean and functional layout that prioritises user experience, ensuring intuitive navigation while supporting differentiated content access for trainees and trainers through role-based permissions. Upon visiting the public domain <https://moodle.vrvet.biba.uni-bremen.de> users encounter a customised login page. The interface features secure authentication fields, ensuring appropriate visibility and functionality across different user categories.

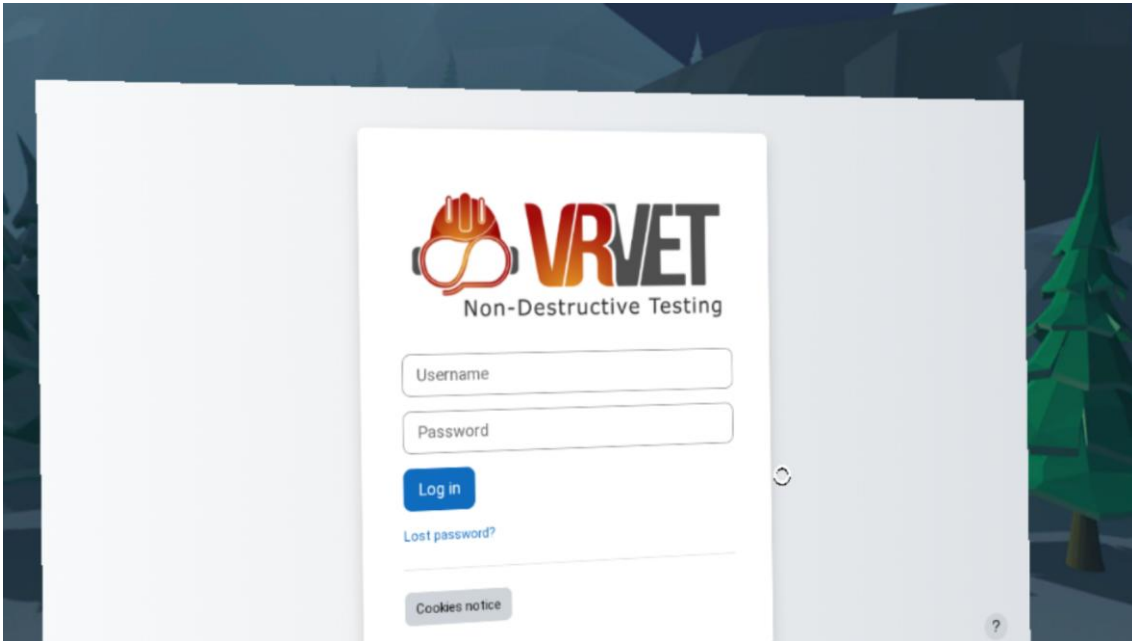


Figure 2: Platform Login Interface

After successful login, users are taken to a structured main dashboard that functions as the central navigation hub. The dashboard includes sections for VR scenario packages, training materials, and documentation.

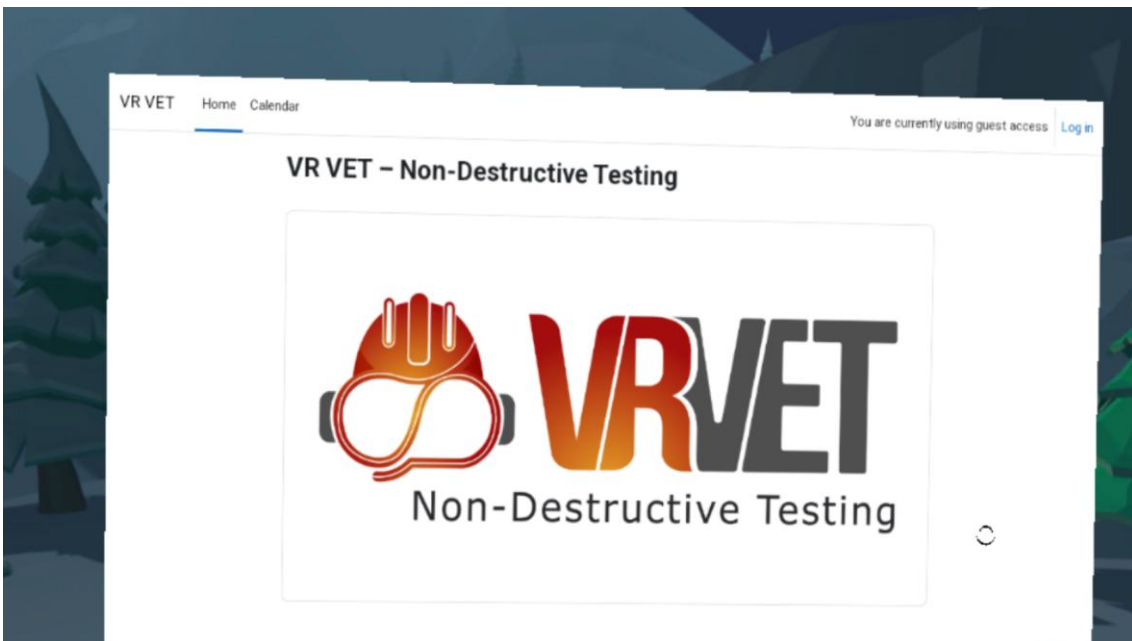


Figure 3: Main Dashboard

Currently, VR training scenarios are made available as .apk installation files that can be manually downloaded from the platform. This method allows partner labs to



deploy and test the scenarios independently on *HTC Vive Focus Vision* headsets, while maintaining update control and traceability. Each scenario download includes version metadata and accompanying installation guidelines to ensure proper use across different environments.

In addition, the platform supports direct access from within the VR headset browser. This capability enables users to log in and retrieve scenario files without requiring a desktop intermediary streamlining installation and making content access more flexible for real-world training contexts.



Figure 4: Direct VR Headset Access to Moodle Platform

This interface setup ensures that all users whether accessing via desktop or directly through a VR headset can interact with the training platform in a secure, and consistent manner. By combining structured content delivery with flexible access modes, the Moodle-based system effectively supports the transnational deployment of the VR scenarios.

The next section provides a detailed overview of how the VR training scenario is technically implemented, including the interactive architecture and procedural logic embedded within the Unity development environment.

Implementation of Scenarios (Technical Workflow in Unity)



The Penetrant Testing scenarios are implemented in Unity using a modular, event-driven workflow architecture. This architecture coordinates the procedural sequence, interaction handling, object behaviour, and training feedback within a single controlled system. The implementation is structured across several technical layers that operate on top of Unity's *XR Interaction Toolkit (XRI)*, *OpenXR* input runtime, the *PhysX* simulation engine, and *custom C#* components purpose-built for VR interaction stability.

1. Central Scenario State Controller

The procedural workflow is managed by a centralised state controller implemented as a staged logic system.

Each procedural phase (cleaning, penetrant application, excess removal, developer application, inspection, and evaluation) is configured as an independent state, with the controller responsible for:

- Activating and deactivating scene objects per stage
- Enabling and restricting interaction permissions
- Resetting and preparing tools for use
- Triggering UI instructions and guidance elements
- Handling event-driven transitions

All stage transitions are executed in a controlled order, preventing premature activation and ensuring that the trainee completes required actions before progressing.

2. Input and Interaction Pipeline

The interaction layer is implemented using *Unity's OpenXR* runtime, the *XR Interaction Toolkit (XRI)*, and the *Unity Input System*. Together, these components form a unified pipeline through which all controller inputs, locomotion gestures, object handling, and tool activations are processed during the training workflow.

The pipeline uses an *Action-Based Controller* architecture, where all input is defined as *OpenXR* actions and bound to device profiles supported by the *HTC Vive Focus*



Vision. The *Unity Input System* exposes these bindings through an action map that includes the primary channels required for the NDT workflow:

- **Trigger:** activation of tools such as spray bottles
- **Grip:** object grabbing, releasing, and selection
- **Joystick axes:** teleportation arc and continuous directional movement
- **Primary / Secondary buttons:** auxiliary confirmations
- **Haptic output:** feedback during validation events

These actions are routed through the *XR Interaction Toolkit*, which manages object-level events such as:

- `OnSelectEntered` (grabbing a tool)
- `OnSelectExited` (releasing a tool)
- `OnActivated` (trigger press used for spraying)
- `OnHoverEntered / OnHoverExited` (tool proximity feedback)

A simplified example of how interaction callbacks are registered in the Unity workflow is shown below.

```
private void OnEnable()
{
    grabInteractable.selectEntered.AddListener(OnGrab);
    grabInteractable.selectExited.AddListener(OnRelease);
    interactable.activated.AddListener(OnTrigger);
}

private void OnGrab(SelectEnterEventArgs args)
{
    // Tool pick-up logic for the active stage
}

private void OnRelease(SelectExitEventArgs args)
{
    // Tool drop handling and stage validation
}

private void OnTrigger(ActivateEventArgs args)
{
    // Spray or tool activation logic
}
```

Figure 5: Unity XRI callback registration for grab, release, and trigger events



For locomotion, the system integrates Unity's *TeleportationProvider* and *ActionBasedContinuousMoveProvider*, enabling seamless switching between teleportation and continuous movement depending on the scenario stage. Input listeners for each type of locomotion are selectively enabled or disabled based on the active procedural step, preventing unintended motion during precision tasks such as inspection or developer application.

The interaction pipeline is tightly connected to the scenario state controller. When a tool becomes relevant for a given stage, only its associated input listeners are activated. All others remain disabled to prevent accidental triggering or premature stage completion. This stage-dependent activation ensures consistent behavior across devices and provides deterministic control flow regardless of user input variability.

The pipeline is further supported by Unity's *OpenXR* backend, which guarantees accurate mapping to the *HTC Vive Focus Vision* controller profile. This includes correct handling of trigger sensitivity curves, grip force thresholds, joystick deadzones, and controller pose tracking. Through this configuration, the system achieves stable 6DoF interactions and reliable input interpretation across all procedural stages.

3. Collider-Driven Validation Systems

The validation of user actions across all procedural stages in the VR scenario is implemented through a collider-driven detection framework that operates directly on Unity's *PhysX* engine. Throughout the training workflow, surface cleaning, penetrant spraying, excess removal, developer application, and inspection tasks each rely on specialised validation subsystems that continuously sample controller motion, surface contact, and coverage. For cleaning, the cloth tool uses continuous collision sampling through `OnCollisionStay`, where each physics frame the system evaluates contact points, detects the controller's movement vector, and applies a smoothing filter to eliminate noise from natural 6DoF micro-motions. The target weld surface contains an internal grid of sampling nodes; when a validated stroke intersects a node's collider, it is registered as cleaned, allowing objective progression conditions based on percentage coverage. Spray-based stages apply a lightweight ray-based surface



detection method, where each frame, the spray bottle emits a nozzle-aligned ray and coverage values increment proportionally to trigger time, avoiding expensive particle collision calculations while still ensuring realistic application behaviour. The excess-removal logic applies stricter directional validation by evaluating the dot product between the cloth motion and the required wipe direction, ensuring that only purposeful, correctly oriented strokes contribute to stage completion and preventing progression through arbitrary shaking or incidental movements. The developer application follows the same ray-based coverage tracking but uses separate thresholds and surface layers, and inspection validation combines viewing-angle checks with developer coverage values to confirm that the trainee is positioned correctly and has completed all prior steps. Each subsystem communicates with the scenario state controller via event-driven callbacks that notify when thresholds are reached or when correct interactions are detected, enabling deterministic state transitions and preventing premature advancement. This unified collider-driven validation approach ensures procedural accuracy, stable interaction handling on standalone VR hardware, and consistent behaviour regardless of user motion variability.

```
private void OnCollisionStay(Collision collision)
{
    Vector3 motion = transform.position - lastPosition;
    lastPosition = transform.position;

    // Directional validation for controlled wiping
    float alignment = Vector3.Dot(motion.normalized, requiredDirection);

    if (alignment > 0.7f)
    {
        surfaceTracker.RegisterWipeHit(collision.contacts[0].point);
    }
}
```

Figure 6: Implementation of collider-driven directional wiping logic

4. Object Behaviour and Reset System



Interactable tools within the VR scenarios—such as spray bottles, cloths, and auxiliary items—are managed through a controlled behaviour and recovery system to ensure stable handling during training. Each tool is implemented using Unity’s *XRGrabInteractable*, supported by rigidbody physics and custom logic that maintains correct positioning and prevents unintended drifting or misplacement.

When a tool is released, the system performs a brief post-release check to determine whether it remains within an acceptable placement region on the worktable. If the object is dropped outside this zone, rotated incorrectly, or left in an unstable orientation, a reset routine is triggered. During this process, physics is temporarily suspended, collisions are disabled, and the object is smoothly repositioned and reoriented to its predefined start location. Once the reset motion is complete, physics and collisions are restored to allow normal interaction.

This subsystem ensures that all tools consistently remain available, correctly oriented, and free from common standalone VR issues such as jitter, tipping, or sliding due to limited mobile physics fidelity. It contributes to a predictable and reliable training environment where user errors or accidental releases do not interrupt the procedural workflow.



Figure 7: In-scene arrangement of interactable VR tools within the scenario environment, illustrating the objects controlled by the reset and behaviour management systems (*XRGrabInteractable* + physics constraints)

5. Guidance, UI, and Prompt Systems



The guidance layer of the VR training environment provides structured instructional support throughout the penetrant testing workflow. All user-facing feedback is delivered through a coordinated set of world-space UI elements, audio cues, and dynamic visual indicators that respond to the trainee's actions in real time. Core instructions are displayed using *TextMeshPro*-based world-space canvases, positioned directly within the user's field of view and updated through a centralized prompt manager. This component listens to scenario state transitions and replaces text content automatically as each procedural step is completed. The system ensures that prompts remain readable, properly scaled for the *HTC Vive Focus Vision* display, and consistently oriented toward the user through camera-facing billboard logic. Audio guidance is provided via *Unity's AudioSource* and *AudioMixer* systems, enabling synchronized playback of narration and interaction sounds such as spraying, wiping, or stage transitions. All audio events are triggered through state-linked handlers to ensure precise alignment with user progress. Together, these guidance systems create a coherent instructional layer that supports the trainee's situational awareness and ensures correct sequencing of actions without requiring external supervision.



Figure 8: Dynamic world-space prompt displayed during the active training stage, providing real-time procedural guidance to the trainee

6. Build and Runtime Execution Setup



The build pipeline for the VR training scenarios is configured to ensure stability, performance, and full compatibility with the *HTC Vive Focus Vision* headset. The Unity project targets *Android ARM64*, aligned with the device's operating architecture, and uses *IL2CPP* as the scripting backend for improved runtime performance and memory safety. Rendering is optimized through Single Pass Instanced stereo rendering, reducing GPU workload while preserving visual fidelity. The graphics subsystem enables *Vulkan* as the primary API, with *OpenGL ES* retained as a fallback to guarantee cross-device robustness. The XR subsystem is configured exclusively through the *OpenXR* runtime, using the *HTC Vive Focus Vision* interaction profile. Only required features—such as tracking, controller actions, and haptic channels—are enabled to reduce overhead and avoid unnecessary runtime initialization. All project assets are optimized for standalone VR execution through compressed texture formats, GPU instancing, and URP-based shader profiles. The runtime execution is fully self-contained within the *OpenXR* ecosystem, ensuring predictable controller mapping, stable locomotion behavior, and consistent tool interactions across all procedural stages.

The scenario is developed in Unity using a structured workflow that combines stage logic, user interactions, validation mechanisms, and instructional feedback into a seamless training process. Each procedural step functions within an integrated, state-driven framework, making sure that tools, actions, and guidance elements operate consistently and reliably on the *HTC Vive Focus Vision* headset.

Integration of Moodle-Based VR Platform with Scenarios

The Moodle-based VR platform integrates the Unity-developed Penetrant Testing scenario as a core training component embedded within the platform's course structure. The VR scenario functions as the interactive module of the platform, while Moodle provides the organisational, access-control, and resource-management framework. Within this architecture, Moodle serves as the primary entry point through which trainees access the VR module directly from the course environment, using the headset's built-in browser to navigate the VR platform and retrieve the scenario package. This confirms that the scenario is fully embedded in the platform at the content-management level and is visible to end users through the intended VR course pathway.



At the current stage, however, the scenario cannot be executed directly from the Moodle interface when accessed through the headset. This limitation is not related to Moodle or the VR scenario itself, but to the technical behaviour of the headset's system environment, which does not allow VR applications to be launched directly from within the platform interface. As a result, although the scenario is present and accessible as part of the VR course, the execution layer is not yet connected to the platform layer, preventing the scenario from starting when selected inside the headset.

The upcoming technical work focuses on aligning the execution workflow with the device's supported application-launching mechanisms. This includes configuring the scenario so that it can be activated reliably on the HTC Vive Focus Vision while maintaining Moodle as the central organisational, instructional, and administrative environment for VR training. Once this linkage is established, the VR scenario will operate seamlessly alongside the course materials, user guidance, and reporting functions provided through the Moodle-based VR platform.

Living Lab Network

Living Labs are user-centred, real-environment innovation infrastructures designed to support the development, validation, and iterative refinement of emerging technologies under authentic usage conditions. Technically, a Living Lab functions as a hybrid ecosystem in which physical facilities, digital platforms, users, and organisational processes are integrated into a coherent, continuously operating experimentation environment [2] [3].

From a systems-engineering perspective, Living Labs are structured around several core principles:

1. Real-World Operational Context

Living Labs extend beyond controlled laboratory testing by embedding technological solutions directly into environments that replicate operational workflows. Instead of evaluating systems in isolated tests, technologies are deployed in situationally accurate contexts where spatial constraints, environmental factors, natural user



behaviour, and interaction variability can be observed. This allows performance, usability, and procedural alignment to be validated under conditions representative of actual professional practice [2] [3].

2. Active Multi-Stakeholder Participation

A defining characteristic of Living Labs is the intentional involvement of all relevant actor groups. This includes end-users, trainers, domain experts, engineers, and institutional stakeholders. Their role extends beyond passive testing toward active co-creation, where feedback loops, situated evaluations, and iterative assessments guide the refinement of the technological solution. This ensures continuous knowledge exchange between developers and domain specialists [2] [3].

3. Iterative, Experiment-Driven Development

Living Labs follow an iterative development model in which prototypes, tools, or training systems are deployed, tested, assessed, and adapted in repeated cycles. This enables incremental improvement, identification of interaction challenges, and measurement of patterns using structured observations, user analytics, and workflow-specific performance metrics [2] [3].

4. Technological Infrastructure

A Living Lab integrates hardware devices, digital applications, networking layers, and analytics systems into a unified operational environment. Typical infrastructures include:

- Acquisition devices (sensors, VR headsets, controllers, cameras)
- Computational hardware (workstations, standalone processors)
- Software environments (XR applications, LMS platforms)
- Networking layers (LAN/Wi-Fi connectivity, cloud services)
- Data-collection and analysis systems (LRS, monitoring dashboards)



This multi-layered setup enables both real-time execution and systematic data acquisition for evaluation and research [2] [3].

5. Evaluation and Pedagogical/Operational Alignment

Living Labs assess the alignment of technologies with operational, procedural, and pedagogical standards. This includes ergonomics, task realism, clarity of guidance, accuracy of execution, error classification, cognitive load, and compliance with safety requirements. The goal is to ensure that digital or immersive training solutions reflect real-world constraints and authentic domain practices [2] [3].

6. Collaborative Structure

In multi-institutional projects, Living Labs operate as distributed nodes connected through a shared digital platform. Each node functions as a local deployment site with its own users and hardware, while all nodes are unified by a centralised learning environment, shared data structures, and consistent technical configurations. This allows results, improvements, and evaluation outputs from one location to be compared and utilised across the entire network [2] [3].

The core principles outlined above correspond to the Living Lab concept established earlier in the project, where Living Labs were defined as user-centred, real-environment experimentation spaces that integrate technology, stakeholders, and organisational processes. Reiterating this definition is essential for contextualising the VR-VET implementation, as the project applies these principles directly to its network of partner institutions. In the following section, the conceptual Living Lab introduced in earlier documentation is translated into its operational form within VR-VET, describing how each participating institution functions as a Living Lab node, how these nodes are connected through the Moodle-based VR platform, and how responsibilities are distributed between the central hub at *BIBA* and the local partner laboratories.



Definition of Living Lab in Project Context

In the project context, a Living Lab represents the implementation of a user-centred, practice-oriented experimentation space embedded directly within the operational environment of each participating institution. Each site provides the physical infrastructure required for VR-based Penetrant Testing training, including an *HTC Vive Focus Vision* headset, an allocated VR workspace, and the local computing or network resources necessary for stable operation. These facilities enable trainees and instructors to perform VR training tasks under authentic vocational conditions, in line with the Living Lab principle of evaluating technological solutions within real-world usage environments.

The Living Labs are technically linked and coordinated through the Moodle-based VR platform hosted at *BIBA*. This platform functions as the central access node from which all partner institutions obtain the VR scenario package, course materials, documentation, and user support resources. Each institution is provided with dedicated login credentials and institution-level access rights, ensuring secure authentication and controlled participation across the network. The platform is publicly accessible under the configured *BIBA* domain, while permissions within it remain regulated through Moodle's role-based access system. This centralised approach ensures that all nodes operate on a unified platform structure with consistent content, versioning, and configuration.

Connectivity between the distributed Living Labs is established entirely through Moodle's web-based architecture. The *HTC Vive Focus Vision* headsets and institutional systems access the platform via secure *HTTPS* connections, allowing local VR labs to open the VR platform through the built-in browser, retrieve the scenario package, and access training materials directly within the device. VR scenario updates, documentation revisions, and course modifications are administered centrally at *BIBA*, ensuring that all participating nodes operate with uniform and synchronised content.

Through this configuration, the geographically distributed Living Labs function as a coordinated operational network. Although each partner institution executes the VR scenario locally on its own hardware, all nodes remain synchronised through the central Moodle hub, which manages content hosting, user accounts, permissions, and platform-wide configuration. As the project progresses, this architecture will support



integrated performance tracking through *xAPI* and an *LRS*, enabling centralised collection, harmonisation, and analysis of training data across all Living Lab sites.

Overall, the Living Lab setup in VR-VET reflects the project's implementation of a distributed, multi-site training environment. Each partner institution operates as an independent VR training node equipped with the required hardware, local support infrastructure, and authenticated access to the Moodle hub at *BIBA*. Together, these nodes form a transnational Living Lab network that supports VR training delivery, maintained through centralised platform management and a scalable technical foundation for cross-institutional deployment and evaluation.

Network Structure and Partner Roles

BIBA Living Lab: Central Hub and Technical Development Node

Within the project architecture, the Living Lab set up at *BIBA* constitutes the central operational and infrastructural hub that ensures the technical integrity, coordination, and synchronisation of the entire transnational VR-based training network. In alignment with the Living Lab principles previously defined in the project, the *BIBA* node functions simultaneously as the primary physical experimentation site, the principal integration and validation environment, and the central digital access hub through which all partner institutions interact with the Moodle-based VR platform. This dual physical-digital configuration positions *BIBA* as the reference implementation against which all other Living Lab nodes benchmark their own configurations, ensuring methodological coherence and technological consistency across the distributed network.

From a physical infrastructure perspective, the Living Lab at *BIBA* comprises an equipped VR training environment specifically configured to host, evaluate, and validate the VR scenario. The laboratory includes an *HTC Vive Focus Vision* headset, a dedicated VR deployment area designed in accordance with ergonomic and safety standards, and local computing resources that support scenario testing, build verification, and functional quality assurance. This setup serves as the primary site for scenario verification and stability assessment before scenario builds are distributed across the network.



Parallel to this physical VR environment, *BIBA* operates the centralised server infrastructure that hosts the Moodle-based VR platform. This digital infrastructure is set up within *BIBA*'s institutional IT environment on a secure and scalable configuration, incorporating virtualised multi-core processors, SSD-based high-performance storage, GDPR-compliant data handling, and HTTPS-secured access points. Institutional user accounts, partner-specific permissions, and role-based access structures are administered centrally by *BIBA*. Partner institution credentials are currently being finalised and will be integrated into this central access architecture to ensure uniform authentication across the distributed network.

In addition to its core VR training infrastructure, the Living Lab set up in *BIBA* is further supported by the institute's Gaming Lab facilities, which provide an extended technical environment for immersive application development, evaluation, and co-creative testing. These facilities expand the laboratory's capabilities beyond the standard VR setup by offering a broader spectrum of interactive technologies, including VR/AR head-mounted displays, multi-touch interaction surfaces, IoT prototyping toolkits, and mixed-reality development stations. This wider ecosystem enables the Living Lab to serve not only as a deployment site for the VR-VET training scenario but also as a co-design and experimentation environment in which interaction concepts, interface designs, spatial layouts, and technical refinements can be iteratively developed and validated under controlled, yet realistic, conditions. The availability of a dedicated testing zone within the Gaming Lab ensures high-fidelity evaluation of prototype builds under different spatial and operational constraints before updates are deployed to partner labs.

The operational integration of the Gaming Lab resources enhances the role of *BIBA* as the central node within the project's distributed Living Lab network. By supporting both the development and validation of VR training content, the *BIBA* node ensures that all updates released through the Moodle platform originate from a rigorously tested, technically verified baseline configuration. This guarantees that partner institutions receive stable and consistent scenario builds, harmonised with the reference environment maintained at *BIBA*. Through this expanded infrastructure combining VR deployment spaces, serious gaming development environments, IoT testbeds, and centralised platform hosting, *BIBA* provides a comprehensive technical foundation for coordinating VR training activities, maintaining transnational interoperability, and supporting iterative enhancement of the training system across the project's lifecycle.



Figure 9: XR/VR/AR infrastructures available within the Living Lab setup at *BIBA*, illustrating *BIBA*'s technical capacity for immersive co-creative development and interactive system validation supporting the VR-VET ecosystem

BIBA: Living Labs Network Node Information

Each Living Lab node is identified under the internal format **LL-[Partner Acronym]**, for example, **LL-BIBA**.

These Identifiers will be referenced in all future datasets, Moodle configuration records, and related project documentation.

1. Living Lab Identification

Field	Details
Lab ID	LL-BIBA
Institution / Organization	BIBA – Bremer Institut für Produktion und Logistik GmbH
Country	Germany
City / Site of Setup	Bremen
Type of Training Area	Dedicated VR Zone / Laboratory / Serious Gaming Lab
Approximate Area (m²)	~20–25 m ² safe VR interaction space



Functional Network	Role in	Central Moodle Hub Administrator, Development (VR platform and Scenario), VR Training
Physical Description	Layout	Dedicated VR zone within the BIBA Gaming Lab, 4–5 m safe interaction space, floor-marked VR boundary, space for scenario testing and development
Maximum Trainees	Concurrent	1 active VR trainee (plus instructor / observer)
Usage Model		Dedicated VR area integrated into the BIBA Gaming Lab infrastructure
Safety and Accessibility Provisions		Floor boundary markers, obstacle-free zone, cable-free standalone VR setup, controlled lighting, ergonomic calibration area

2. VR Hardware Configuration

2.1 VR Hardware Subsystem

Component	Specification / Model	Quantity	Technical Notes
VR Headset	HTC Vive Focus Vision	1	Primary device used for scenario development
Connection Mode	PC-tethered	-	-
VR-Ready PC / Laptop	Development PC (Windows 10/11, Multi-Core CPU, Dedicated GPU, 16–32GB RAM)	-	Used for Unity development
External Display	-	-	-
Network Interface	Institutional Wi-Fi + LAN	-	-
		-	



Storage Medium	SSD-based institutional storage		High-speed storage used for Moodle hosting, build uploads, and backup replication
Power and Safety Compliance	Standard lab power grid, protected environment	-	Stable power supply; VR zone cleared of obstacles
Other Equipment / Accessories (Procured or Existing)	PCs, Tablets, multi-touch screens, VR glasses	-	Available through BIBA Gaming Lab to support broader Living Lab activities

2.2 Platform Integration Layer

Parameter	Details
Institutional Network Type	Secure institutional Wi-Fi and LAN within BIBA's IT environment. Outbound access to Moodle is unrestricted; HTTPS fully supported; no firewall blocking
VR Area / Lab Preparedness	Dedicated VR zone prepared with controlled lighting, floor marking, defined safe zone
Estimated Number of Trainees	-

3. Operational Context and Usage Profile

Field	Details
Intended Use Case	Development, VR Training, Demonstration
Expected No. of Users per Cycle	1 trainee per session (+ instructor)
Instructor Support Mode	Physical supervision within lab
Environmental Conditions Impacting VR	Controlled lighting; low noise; stable Wi-Fi; minimal interference; optimised for tracking stability



Observed Usability / Ergonomic Factors	Stable 6DoF tracking, good headset comfort, minimal drift; no major spatial constraints
Overall Operational Readiness	Operational and Actively Used for Development

4. Documentation and Media



Item	Details
Photos / Diagrams	 
Supporting Layouts / Schematics	VR zone floor layout and workstation configuration
Additional Technical Notes	-

Table 1: Living Lab Network Node Information (BIBA)



The Living Lab setup at *BIBA* provides both the physical VR training environment and the centralised digital platform infrastructure required to support the entire network of partner institutions. It therefore functions as the reference node for configuration, validation, and coordinated operation within the VR-VET Living Lab ecosystem.

Partner Living Labs: Local VR Training and Testing Environments

The distributed architecture of the *VR-VET* ecosystem comprises multiple Living Lab nodes across participating partner institutions. While the Living Lab setup at *BIBA* serves as the central hub for development and coordination, partner nodes act as sites, responsible for testing, local validation, and delivering scenario-based VR training. These laboratories act as regional access points for the Moodle-based platform, hosting validated training scenarios, supporting immersive procedural education, and contributing empirical feedback for iterative system refinement.

To ensure interoperability, safety, and technical alignment across this transnational network, all partner institutions were requested to establish their local VR training environments in accordance with the Living Lab specifications defined in the project and to document their hardware, software, spatial, and operational readiness via a standardised technical coordination form. The data obtained through these forms forms the basis for assessing and verifying the deployment status of each local node. It directly contributes to the consolidation of a coherent and interoperable Living Lab network that supports the project’s distributed training architecture.

The structured configurations received thus far from some of the project partners are presented below. These records demonstrate the establishment of institution-specific VR zones equipped with standardised devices, safety protocols, and support frameworks compatible with the scenario content developed at the central node. This setup ensures that each local lab can support the training content under controlled and validated technical conditions while maintaining alignment with the reference environment.

Living Lab Setup: CESOL

1. Living Lab Identification

Field	Details



Lab ID	LL-CESOL
Institution / Organization	CESOL
Country	Spain
City / Site of Setup	Madrid
Type of Training Area	Classroom
Approximate Area (m²)	60 m ²
Functional Role in Network	VR Training / Demonstration / Blended Training
Physical Layout Description	-
Maximum Concurrent Trainees	20 (Sitting on the chairs)
Usage Model	-
Safety and Accessibility Provisions	-

2. VR Hardware Configuration

2.1 VR Hardware Subsystem

Component	Specification / Model	Quantity	Technical Notes
VR Headset	HTC Vive Focus Vision	6	-
Connection Mode	-	-	-
VR-Ready PC / Laptop	-	1	-
		1 monitor	



External Display	-	1 projector 1 smartboard	-
Network Interface	-	LAN cable and Wi-Fi	-
Storage Medium	-	-	-
Power and Safety Compliance	-	-	-
Other Equipment / Accessories (Procured or Existing)	-	-	-

2.2 Platform Integration Layer

Parameter	Details
Institutional Network Type	-
VR Area / Lab Preparedness	-
Estimated Number of Trainees	-

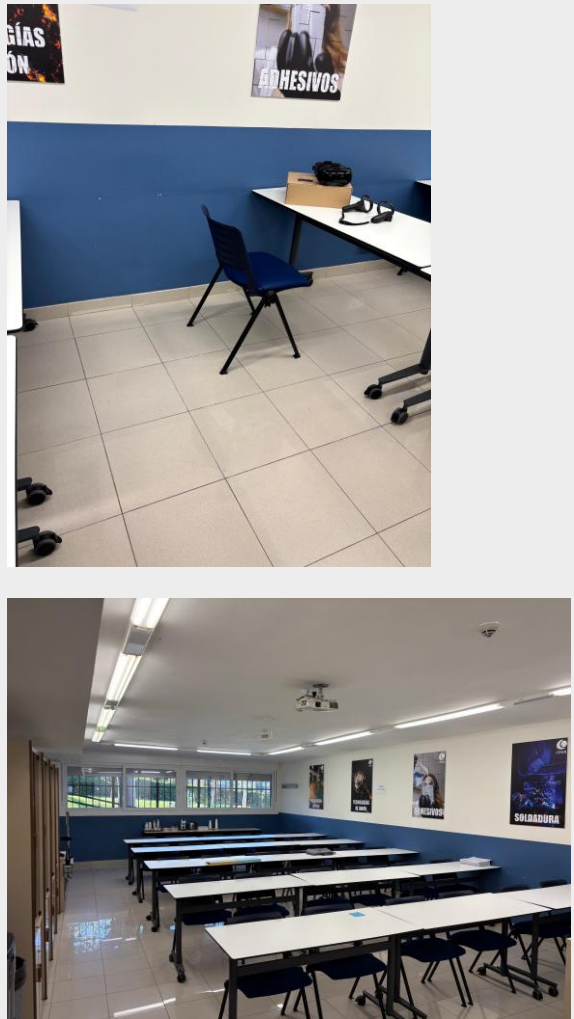
3. Operational Context and Usage Profile

Field	Details
Intended Use Case	VR Training / Demonstration
Expected No. of Users per Cycle	Approximate number of trainees per session: Between 6 and 10
Instructor Support Mode	Physical presence



Environmental Conditions Impacting VR	Lighting, noise, Wi-Fi interference, or other environmental factors affecting headset performance
Observed Usability / Ergonomic Factors	Headset comfort, tracking accuracy, user fatigue, or motion constraints observed during device testing sessions
Overall Operational Readiness	Functional / Under Testing / Pending Setup / In Development

4. Documentation and Media

Item	Details
Photos / Diagrams	




	
Supporting Layouts / Schematics	-
Additional Technical Notes	-

Table 2: Living Lab Network Node Information (CESOL)

Living Lab Setup: IPUNTO

1. Living Lab Identification

Field	Details
Lab ID	LL-ipunto
Institution / Organization	ipunto
Country	Spain
City / Site of Setup	Madrid
Type of Training Area	Laboratory / Classroom



Approximate Area (m²)	4 m ²
Functional Role in Network	VR Training / Demonstration
Physical Layout Description	Classroom setup 4 m ² area for VR with the computer to the left of the VR area and a projector in the ceiling and the screen in the wall
Maximum Concurrent Trainees	3
Usage Model	Shared classroom and VR
Safety and Accessibility Provisions	Perimeter boundaries, supervision protocol

2. VR Hardware Configuration

2.1 VR Hardware Subsystem

Component	Specification / Model	Quantity	Technical Notes
VR Headset	HTC Vive Focus Vision	-	-
Connection Mode	PC-tethered	-	-
VR-Ready PC / Laptop	Laptop model: Victus by HP Gaming Laptop 16-s0xxx CPU:AMD Ryzen 7 7840HS w/Radeon 780M Graphics, 3801 Mhz, 8 main processorl and 16 logical processor cpu RAM: 32GB OS version:Windows 11 pro	-	The system is dedicated to VR
External Display	-	-	-
Network Interface	LAN / Wi-Fi	-	LAN cable or institutional Wi-Fi



			<ul style="list-style-type: none"> • latenc—39ms • Good stability
Storage Medium	HDD	1	<ul style="list-style-type: none"> • Storage capacity 953,86 GB
Power and Safety Compliance	grid circuit	1	-
Other Equipment / Accessories (Procured or Existing)	-	-	-

2.2 Platform Integration Layer

Parameter	Details
Institutional Network Type	LAN and Wi-Fi no restrictions
VR Area / Lab Preparedness	A space of 4 m ² has been designated for VR, marked boundaries and supervised training sessions for first-time
Estimated Number of Trainees	6

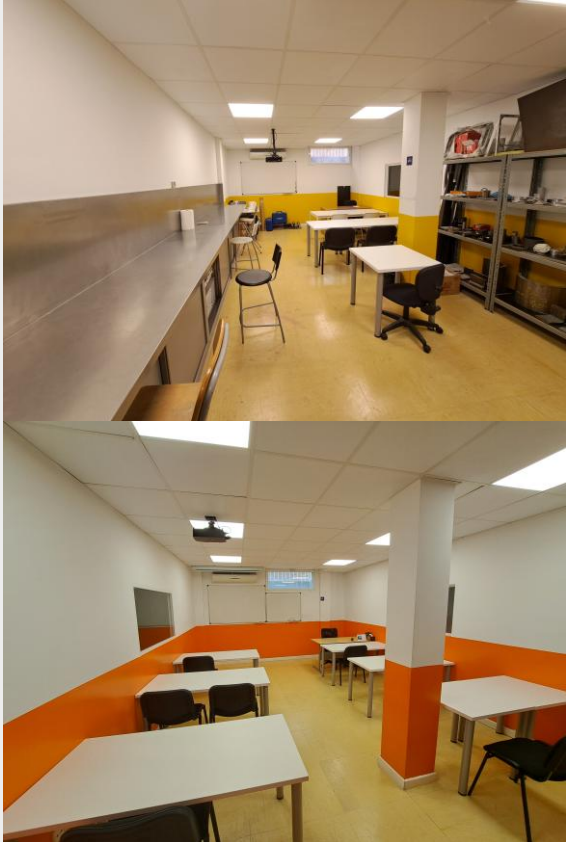
3. Operational Context and Usage Profile

Field	Details
Intended Use Case	VR Training
Expected No. of Users per Cycle	6
Instructor Support Mode	Physical presence
Environmental Conditions Impacting VR	-



Observed Usability / Ergonomic Factors	-
Overall Operational Readiness	Functional

4. Documentation and Media

Item	Details
Photos / Diagrams	



	
Supporting Layouts / Schematics	-
Additional Technical Notes	-

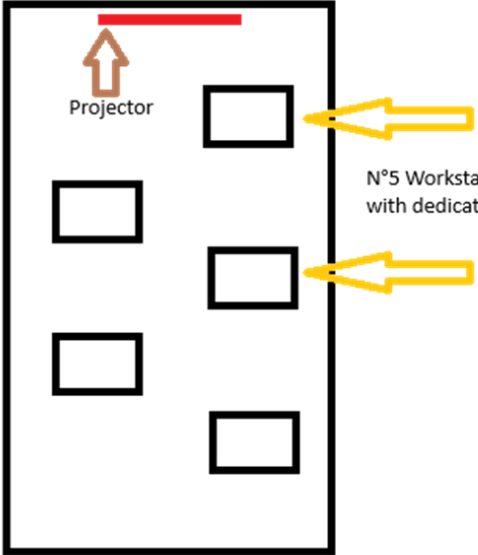

Table 3: Living Lab Network Node Information (IPUNTO)

Living Lab Setup: Walter Tosto

1. Living Lab Identification

Field	Details
Lab ID	LL-WT
Institution / Organization	Walter Tosto Spa
Country	Italy
City / Site of Setup	Chieti
Type of Training Area	Classroom
Approximate Area (m²)	32mq
Functional Role in Network	VR Training / Demonstration / Testing



Physical Layout Description	<p>2x2m safe zone per person; workstation as image below</p> <p>Room 4*8m = tot 32m²</p>  <p>The diagram shows a rectangular room with a red horizontal bar at the top representing a 2x2m safe zone. An orange arrow labeled 'Projector' points upwards from the top-left corner. Five black rectangular boxes represent workstations, arranged in a vertical column on the right side of the room. Two yellow arrows point to the top and middle workstations, with the text 'N°5 Workstation with dedicate PC' next to them.</p>
Maximum Concurrent Trainees	5
Usage Model	Permanent VR area
Safety and Accessibility Provisions	<p>As image below</p>  <p>The photograph shows a classroom with several white tables and green chairs arranged in rows. A green chalkboard is visible on the right wall.</p>

2. VR Hardware Configuration

2.1 VR Hardware Subsystem

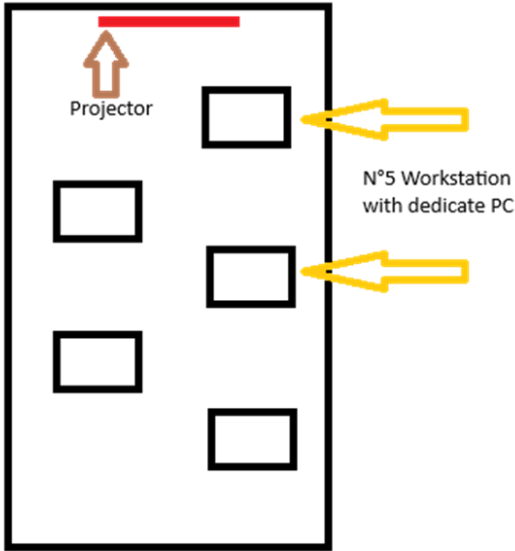


Component	Specification / Model	Quantity	Technical Notes
VR Headset	HTC Vive Focus Vision	Actually 1 Next Future 5	-
Connection Mode	Standalone / PC-tethered	Standalone Connection type = USB	-
VR-Ready PC / Laptop	-	Actually 1 Next Future 5 HP PRO BOOK 4 G1I 16 + Intel Core Ultra 5 225H + RTX 3050 + 16GB +Windows 11 Pro Dedicated to VR	-
External Display	-	1 Projector Connection type = HDMI Instructor monitoring / Group demonstration / Streaming	-
Network Interface	-	Actually = Wi-Fi	-
Storage Medium	-	PC = 500GB SSD	-
Power and Safety Compliance	Power Supply Environment /	We have stable power source, adequate floor space, with supervisor	-
Other Equipment / Accessories	-	N0 1 = 9 Port HDMI Multi-View Switch	



(Procured or Existing)		Actually 1 Next Future 5 Kit for VR connection HDMI optical Cables Mouse	
-------------------------------	--	--	--

2.2 Platform Integration Layer

Parameter	Details
Institutional Network Type	-
VR Area / Lab Preparedness	<p>As image below</p> <p>Room 4*8m = tot 32m2</p> 
Estimated Number of Trainees	Number of Trainees = 2 Number of learners = as much as possible

3. Operational Context and Usage Profile

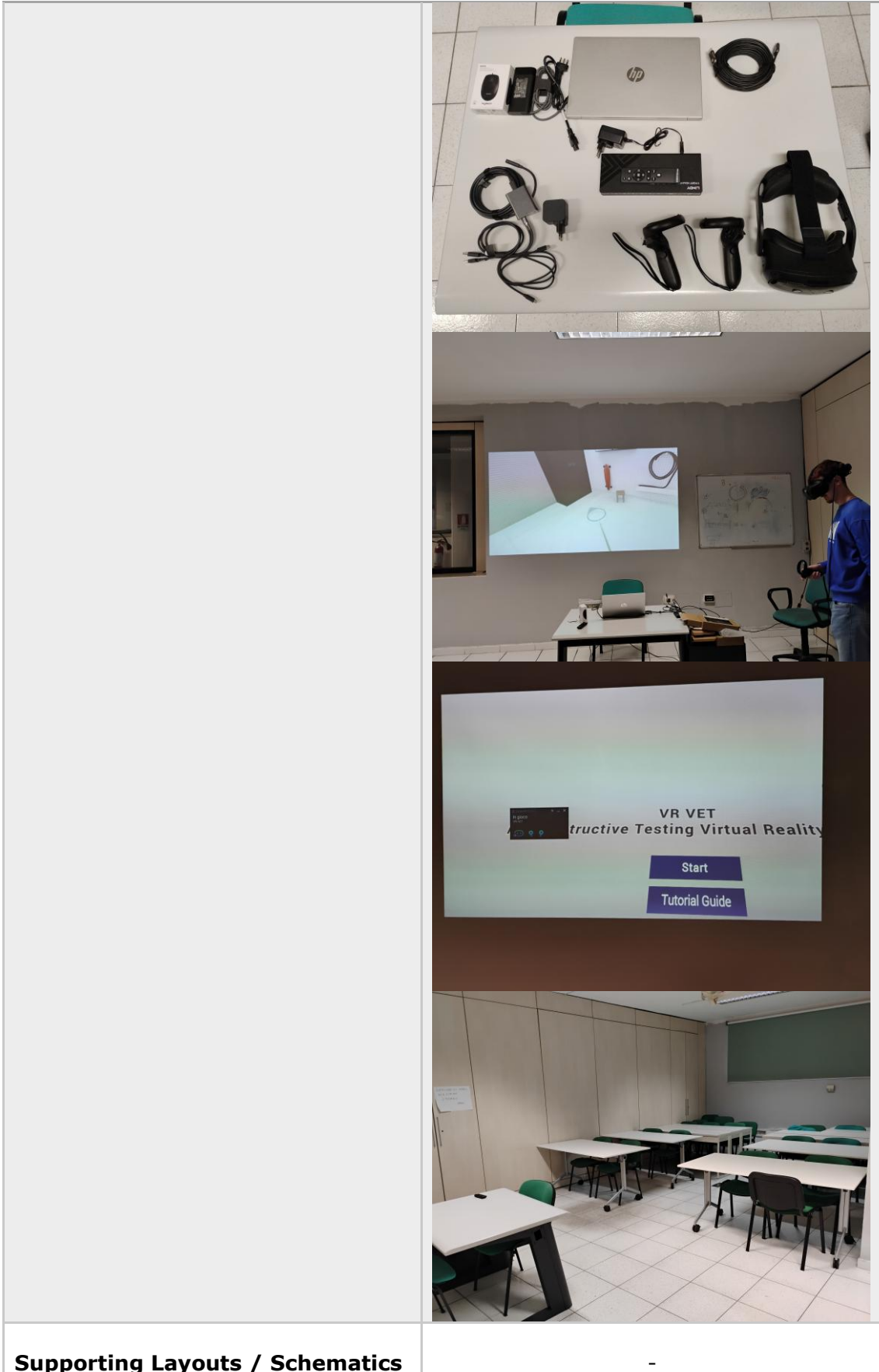
Field	Details
Intended Use Case	VR Training / Demonstration
Expected No. of Users per Cycle	Number of Trainees = 2 Number of Users per Cycle = 5
Instructor Support Mode	Physical presence



Environmental Conditions Impacting VR	-
Observed Usability / Ergonomic Factors	Tired eyes after 1 hour
Overall Operational Readiness	Under Testing

4. Documentation and Media

Item	Details
Photos / Diagrams	



Supporting Layouts / Schematics

-



Additional Technical Notes	-
-----------------------------------	---

Table 4: Living Lab Network Node Information (Walter Tosto)

Living Lab Setup: ISIM

1. Living Lab Identification

Field	Details
Lab ID	LL-ISIM
Institution / Organization	ISIM
Country	Romania
City / Site of Setup	Timișoara
Type of Training Area	Classroom
Approximate Area (m²)	100 m ²
Functional Role in Network	VR Training / Demonstration
Physical Layout Description	-
Maximum Concurrent Trainees	11 (Sitting on the chairs)
Usage Model	-
Safety and Accessibility Provisions	-

2. VR Hardware Configuration

2.1 VR Hardware Subsystem

Component	Specification / Model	Quantity	Technical Notes
VR Headset	HTC Vive Focus Vision	6	-



Connection Mode	PC-tethered -	-	-
VR-Ready PC / Laptop	-	6 pc units 1 laptop	PC units: - Intel Core i5-13400 - GIGABYTE -B760 - RAM: 32GB - 1TB SSD Samsung 990 PRO Windows 11 pro Laptop: - ASUS TUF A16 FA608WV - AMD Ryzen™ AI 9 HX 370 (24M Cache, up to 5.10 GHz) - 16" 2.5K 165Hz - 32GB DDR5 - 1TB SSD - NVIDIA GeForce RTX 4060 @8GB, DLSS 3.0 -
External Display	-	1 projector 1 smartboard	Projector: - Epson EB-815E - Full HD 1920 x 1080, - 3LCD - laser - 5000 lights Smartboard: - 65" Interactive Signage Flip
Network Interface	-	LAN cable and Wi-Fi	-
Storage Medium	SSD-based institutional storage	-	High-speed storage used for Moodle hosting, build uploads, and backup replication
Power and Safety Compliance	Standard lab power grid, protected environment	-	Stable power supply and VR zone without obstacles
Other Equipment / Accessories	-	-	-



(Procured or Existing)			
-------------------------------	--	--	--

2.2 Platform Integration Layer

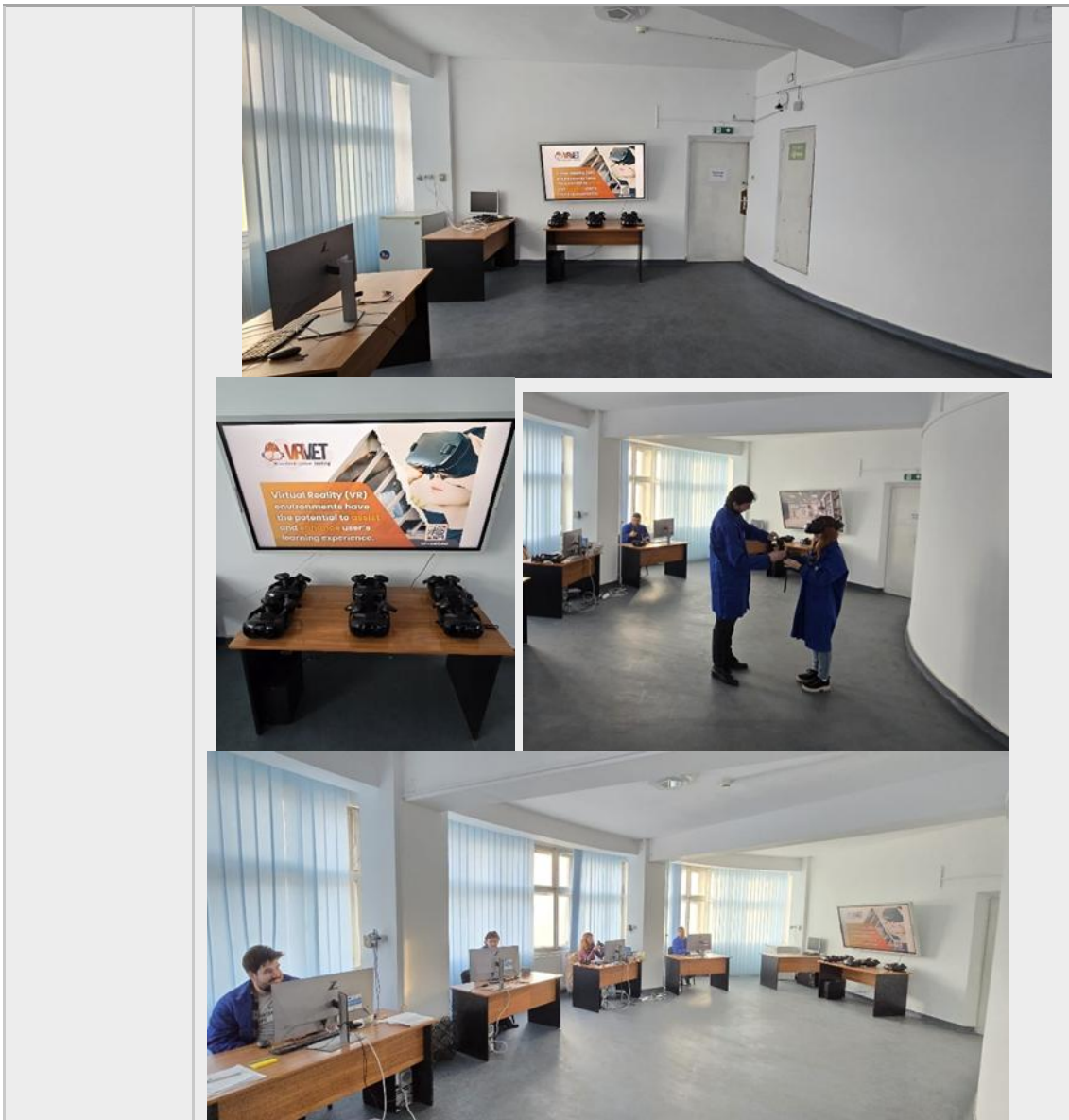
Parameter	Details
Institutional Network Type	LAN and Wi-Fi no restrictions
VR Area / Lab Preparedness	spaces of >2 m ² has been designated for VR training sessions
Estimated Number of Trainees	Approximate number of trainees per session: Between 2 and 4

3. Operational Context and Usage Profile

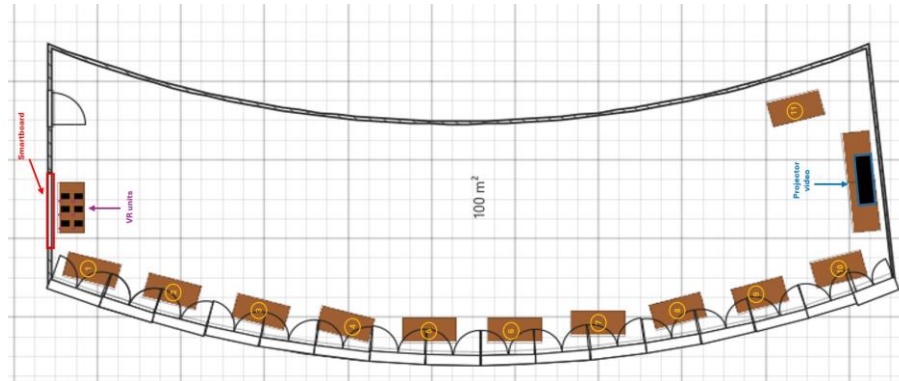
Field	Details
Intended Use Case	Dedicated VR Zone / VR Training / Demonstration
Expected No. of Users per Cycle	Number of Trainees between 2-4 Number of Users per Cycle between 4-6
Instructor Support Mode	Physical presence
Environmental Conditions Impacting VR	-
Observed Usability / Ergonomic Factors	Tired eyes after 1 hour
Overall Operational Readiness	Under Testing

4. Documentation and Media

Item	Details
Photos / Diagrams	



**Supporting
Layouts /
Schematics**



**Additional
Technical
Notes**

The ISIM NDT Laboratory conducts training and certification activities in alignment with SR EN ISO 9712, focusing primarily on the preparation of personnel for Level 1 and Level 2 qualification in major non-destructive testing methods. Training programs combine



	<p>theoretical instruction with structured practical sessions, supported by standardized procedures, calibrated equipment, and examination formats consistent with industry expectations. Current NDT training courses delivered within ISIM include:</p> <ul style="list-style-type: none"> • Visual Testing (VT) – Level 1 & 2 • Liquid Penetrant Testing (PT) – Level 1 & 2 • Magnetic Particle Testing (MT) – Level 1 & 2 • Ultrasonic Testing (UT) – Level 1 & 2 • Radiographic Testing (RT) – Level 1 & 2 <p>These training activities integrate method-specific learning objectives, demonstrations, laboratory practice, defect evaluation exercises, and standardized reporting formats. Personnel qualification records, calibration data, and examination documentation support traceability and consistency throughout the training process. Practical sessions emphasize real-equipment operation, inspection parameter selection, defect recognition, and correct application of procedural steps, forming the core of ISIM’s approach to skill development.</p> <p>As modern NDT practice evolves, the training environment benefits increasingly from technologies that improve realism, repeatability, and student engagement. Virtual reality represents a significant enhancement in this context, enabling controlled simulations of inspection tasks, complex geometries, difficult-to-access environments, and hazardous scenarios that are not easily reproduced in a traditional classroom. Through projects such as VR-VET, ISIM advances toward an integrated training model in which immersive VR modules complement existing theoretical and practical instruction, reinforcing operator confidence, supporting better retention of procedural steps, and creating a safer, more adaptable learning environment. This approach strengthens the overall effectiveness of NDT training and aligns the laboratory with modern educational and industrial trends.</p>
--	--

Table 5: Living Lab Network Node Information (ISIM)

Living Lab Setup: IIS

1. Living Lab Identification

Field	Details
Lab ID	LL-IIS
Institution / Organization	Istituto Italiano della Saldatura (IIS)
Country	Italy



City / Site of Setup	Genova
Type of Training Area	VR Training Zone / Classroom
Approximate Area (m²)	43 m ² VR interaction space
Functional Role in Network	VR Training - Development
Physical Layout Description	The Training room is designed to host eight individual VR stations, each allocated a 2m × 2m safe interaction zone, ensuring sufficient space for user movement and operational safety.
Maximum Concurrent Trainees	8 (Standing and sitting)
Usage Model	Permanent VR area, Training Lab
Safety and Accessibility Provisions	<p>A comprehensive set of safety measures has been implemented within the classroom environment to ensure a secure, controlled, and inclusive learning setting.</p> <p>These measures encompass clearly defined physical and operational boundaries of the training area, established supervision and instructor oversight protocols during all training activities, adequate ventilation and environmental control systems, and full compliance with accessibility requirements to accommodate diverse user needs.</p> <p>Such provisions are designed to support both conventional and advanced training modalities, including immersive and virtual reality-based activities, ensuring safe operation, user well-being, and conformity with applicable institutional and regulatory standards.</p>

2. VR Hardware Configuration

2.1 VR Hardware Subsystem

Component	Specification / Model	Quantity	Technical Notes
VR Headset	HTC Vive Focus Vision	8	



Connection Mode	Standalone / PC-tethered	-	At the current stage, the system expected to operate in standalone mode, with the possibility of future expansion to PC- or tablet-based.
VR-Ready PC / Laptop	Development/Testing System Brand and Name: ASUS ROG Strix SCAR 16 CPU: Intel Core Ultra 9 275HX Graphics: NVIDIA GeForce RTX 5090 24GB RAM: 32GB Win 11 Home VR Ready.	-	The system is dedicated to the VR laboratory, intended for the development of VR-related software, testing and collaborative activities within the VR environment.
External Display	1 Projector 1 Smart Display		Projector with Connection type = HDMI 86" Smart Board capable of writing, meetings and calls, control over the VR environment.
Network Interface	LAN / Industrial Wi-Fi	-	
Storage Medium	SSD / Cloud Storage	-	High speed SSD internal storage capacity
Power and Safety Compliance	Standard industrial power grid, protected environment	-	Stable power source and protection
Other Equipment / Accessories (Procured or Existing)	- 8 VR Glasses - Kit for VR connection HDMI optical Cables (same quantity as the VR Glasses) - PC - Smart Screen - Video projector - Tablets	-	-



2.2 Platform Integration Layer

This section collects information that will help verify each lab’s technical readiness to connect with the central Moodle-based VR platform and to launch VR scenarios successfully.

Parameter	Details
Institutional Network Type	The LAN/WIFI are enabled and protected by a firewall double protection which does not block academic and training domains. All the data uploaded and downloaded is Encrypted and secured, guaranteed by use of VPN, proxies and centralized cyber security platform and secure network infrastructure.
VR Area / Lab Preparedness	Adequate lighting, ventilation and environmental control systems, and full compliance with accessibility requirements to accommodate diverse user needs.
Estimated Number of Trainees	Each course series accommodates eight students.

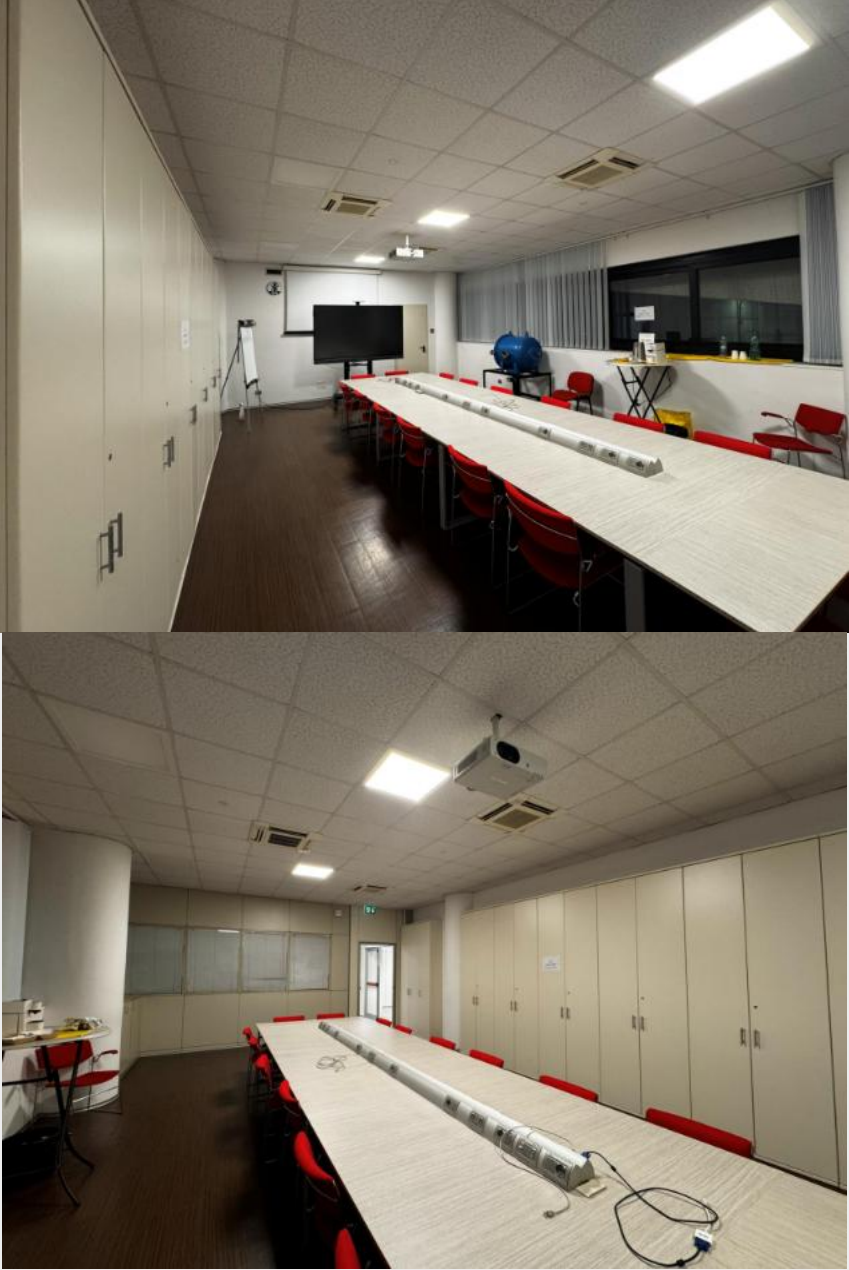
3. Operational Context and Usage Profile

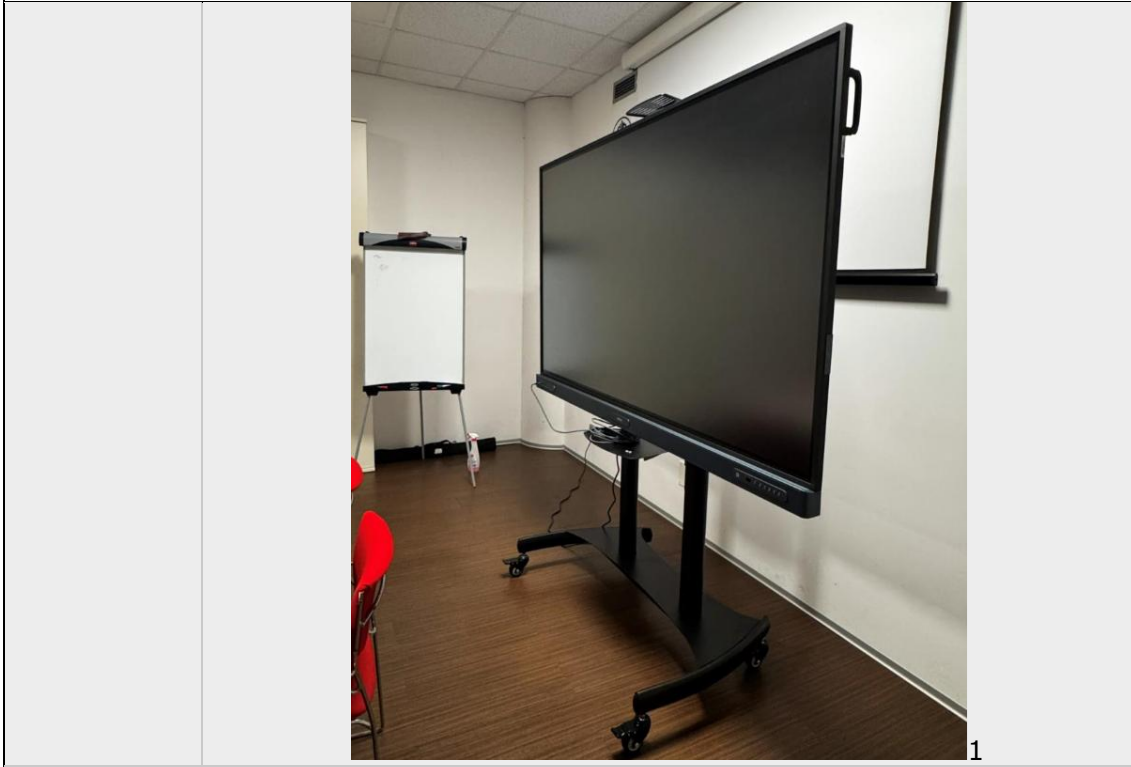
Field	Details
Intended Use Case	VR Training / Development
Expected No. of Users per Cycle	8 per cycle (+Instructor)
Instructor Support Mode	Physical Presence Supervision
Environmental Conditions Impacting VR	Standard Lighting. Standard Noise isolation, Standard institutional safe Wi-Fi interference,
Observed Usability / Ergonomic Factors	Headset comfort, tracking accuracy, user fatigue, or motion constraints observed during device testing sessions Extended use of the VR headsets for beginners resulted in eye strain and nausea.
Overall Operational Readiness	- VR Headset Setup completed,



- Various VR Softwares and games tested for verification of glasses

4. Documentation and Media

Item	Details
<p>Photos / Diagrams</p>	



**Supporting
Layouts /
Schematics**

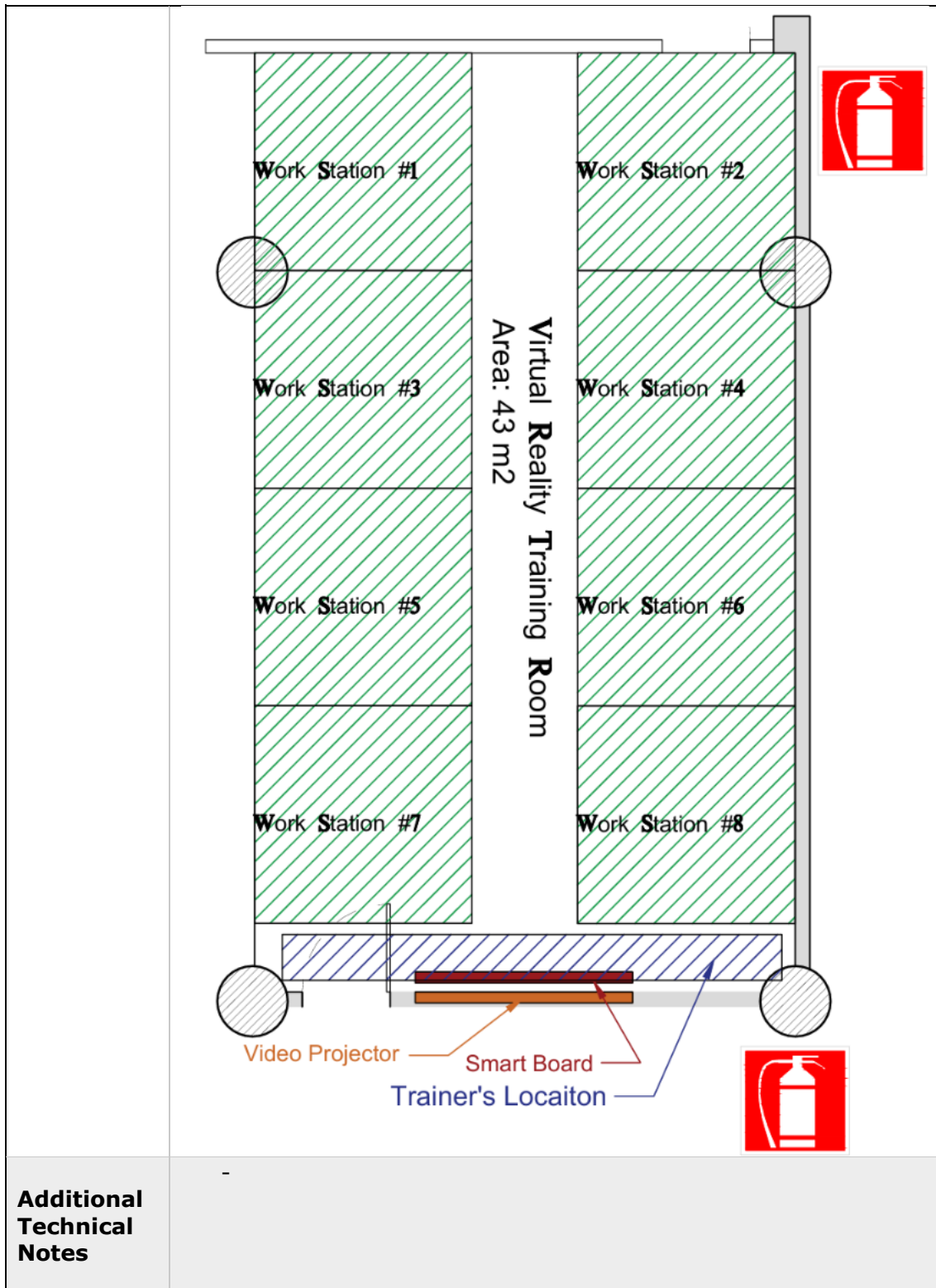


Table 6: Living Lab Network Node Information (IIS)



The above Living Labs specifications show that partner institutions have set up technically robust and pedagogically supportive VR infrastructures. While individual configurations vary from dedicated immersive rooms to integrated training spaces within existing educational facilities—they consistently reflect the project’s emphasis on modularity, system consistency, and deployment fidelity. As the remaining partners finalise their setups, the operational resilience and scale of the *VR-VET* Living Lab network will continue to evolve, ensuring broad access across the consortium.

This established and synchronised network of Living Labs forms the foundation for a seamless flow of validated scenario content, updates, and learner data between nodes. The next section outlines the technical and procedural workflow governing interaction between labs, including how VR content is released, and tested across the *VR-VET* network.

Workflow of Interaction between Labs

The *VR-VET* Living Lab ecosystem is set up as a distributed and coordinated network of institutional nodes, where each partner lab contributes to a shared process for training, scenario testing, and giving feedback for improvements. At the core of this setup is a working process that explains how the Living Labs connect both technically and pedagogically to make sure the training content is used and checked properly.

In the current setup, scenario builds developed and tested at the central lab are shared with partner labs for initial integration and local testing. This first step creates feedback loops between institutions: each lab checks if the scenario works on their hardware, reports any issues or differences, and shares findings through structured coordination. In parallel, integration of the VR scenarios into the Moodle-based VR platform is in progress. Once this pipeline is completed, partner labs will be able to access the VR scenarios using platform login, allowing content updates, version tracking, and user data to be shared in the same system. The Moodle platform will collect training data such as session time, task completion, mistakes, and system responses. This data will be visible to trainers through dashboards for review and reports.

Scenario builds are first developed and validated at the central node. These builds are then shared with partner labs, who locally test them within their own VR environments and provide structured feedback on usability, technical performance, and training effectiveness. In the coming days, validated scenarios will be fully



integrated into the Moodle-based VR platform, enabling partner labs to access, deliver, and monitor training content directly through the centralised system. This supports aligned deployment, continuous improvement, and synchronized training across the *VR-VET* Living Lab network.

System-Level Workflow and Interaction

The *VR-VET* infrastructure operates as a unified system that integrates scenario development, VR platform functionality, and Living Labs across partner institutions. The structure ensures consistency in VR training content, system updates, and data-driven refinement across the transnational network.

At present, the central Moodle-based VR platform hosted at *BIBA* has been set up and serves as the core digital hub for scenario development. Initial VR training scenario has been developed and validated at the central node and were shared with partner institutions for testing within their local VR labs. These labs, now technically aligned with the central setup, have begun local deployment and are collecting structured feedback on usability and performance. While the platform is already operational and user account provisioning has started with accounts created and credential requests initiated the next development phase will finalise the integration of validated VR scenarios directly into the Moodle system. Once integrated, the system will enable logging of student/trainee interactions during training sessions in Unity. These logs will then be exported back into the Moodle VR platform, review, and analysis. This implementation will complete the data loop between training execution and performance reporting.

In practice, this workflow begins when a trainee puts on the VR headset at a local Living Lab and launches the installed scenario content. The scenario developed in Unity records key interaction metrics, including task completions, procedural accuracy, timing, and system events. These logs are automatically generated within the Unity environment and prepared for secure transfer. Once the training session ends, the recorded data is transmitted to the central Moodle-based platform, where it is associated with the trainee's institutional credentials. Trainers and administrators can then access this data via structured dashboards to review progress, identify learning gaps, and evaluate scenario performance.

Upcoming enhancements include integration of VR scenarios into Moodle based VR platform, completion of institutional credentials assignment for platform access, activation of data dashboards for students, trainers and administrators, and iterative



updates to scenario packages based on partner's feedback. This will complete the technical loop that allows all labs to access the latest scenario versions, contribute feedback, and receive synchronised updates.

Conclusion

The deliverable documents the status of the *VR-VET* training infrastructure, detailing both the implementation of the Moodle-based VR platform and the setup of the transnational Living Lab network. The platform, hosted at *BIBA*, is operational with initial user provisioning. The core of the VR scenario has been developed, validated at the central node, and shared with partner institutions for initial testing and feedback collection.

Local VR labs across partner sites have been established and technically aligned with the central configuration. These labs are now engaged in testing the distributed scenarios within their environments and preparing structured feedback for refinement.

In the next phase, full integration of the validated scenarios into the Moodle platform will be completed, enabling unified access, streamlined deployment, and embedded performance tracking across all partner labs. Further updates will focus on improving the platform interface, scenario integration, and incorporating data analytics dashboards. Continued scenario testing, feedback loops, and refinement processes will support system-wide stability and pedagogical effectiveness as the project progresses.

References

1. Vive Focus Vision - Technische Daten für das eigenständige PC-VR-Headset: Vive Deutschland. HTC VIVE - VR, AR, and MR Headsets, Glasses, Experiences. (n.d.-c). https://www.vive.com/de/product/vive-focus-vision/specs/?_gl=1%2A18t6cmc%2A_up%2AMQ..%2A_gs%2AMQ..&gclid=Cj0KCCQjAv628BhC2ARIsAIJIiK-lqYvvi_OXck6AjntgKkR72YcE7IbRyyU49zoc5QrJEmPQp26IxAYaAtYwEALw_wcB
2. VR-VET Project: D2.4 Completion and Approval of the Technical Requirements of the Living Labs VR Platform and Network (2024)
3. Game and Learning Alliance the European Network of Excellence on Serious Games: D8.6 GALA Serious Games Living Labs Test Report (2013)