MASTER

Blending of XR Technology in Learning Methods

2nd Webinar of XR Projects Cluster

Virtual Visions: How XR is Reshaping Training Landscapes

Online | 05 November 2024 | Jesús Rosel Martínez (from MASTER Project)

Content

Purpose

TO SHOW HOW TECHNOLOGICAL AND EDUCATIONAL APPROACHES ARE COMBINED TO HAVE XR-ENHANCED TRAINING RESOURCES AND SOLUTIONS.

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Impact of XR on simulation & training

1. Simulation and simulators

- Simulations implement models over time.
- Models are useful representations of real or imagined systems…
- Simulators are the devices that run the simulations.
- Domains. Training & Education, Industry, Arts, Entertainment, etc.
- HMI. Interfaces through which humans interact with technical systems/(simulators) for control, feedback, monitoring, etc.

ADVANTAGES

- Cost-effectiveness.
- Availability.
- Safety.
- Improved and standard training environments.
- Provision of data.
- Lack of realism (as an advantage).

Disadvantages

- Failure to reflect real-world performances.
- User acceptance.
- Equipment and facility costs.

BELL 407 GX

FRASCA BELL 407 GX SIMULATOR (FFS-B)
www.frasca.com/

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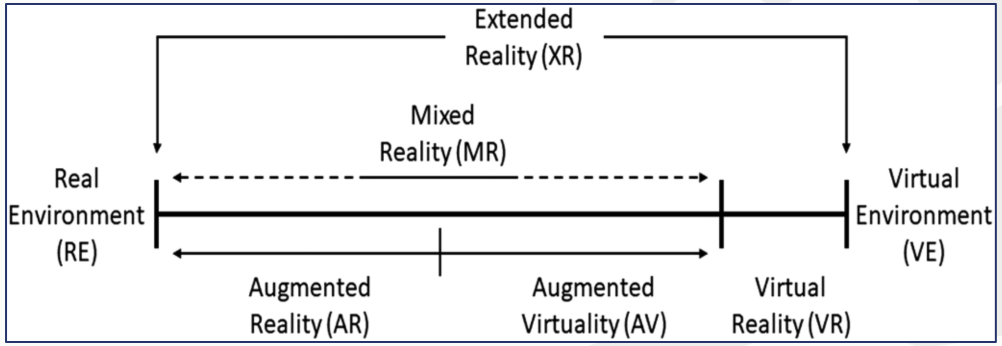
Impact of XR on simulation & training

2. Simulation and XR technology

- Virtual Environments (VE), are digital models that are interactively experienced and manipulated by the VE participant(s), through proper interfaces along the immersion spectrum (from non to full).



BASIC ARCHITECTURE OF THE XR TRAINING SYSTEM

Hard. HMD, tracking, haptics, inputs, computers, peripherals…

Soft. 3D simulation engine, content (scenario modules), feedback…

Networking. Local/Cloud connectivity, collaborative features…

https://parasim.com/

- The distinctive use of XR in simulation and training is based on the affordances of immersion.
- Ful immersion. It is an ideal. Today it is not possible to create a perfect “sense of presence” in a VE.
- Holistic experiences. The strategy. Integrate increasingly better sensory, cognitive, affective, personal and social features in persistent simulation frameworks.

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XR in Simulation and Training

3. Advantages of XR over traditional simulators

FACTORS THAT EXPLAIN THE INCREASING USE OF XR IN TRAINING

- **Technological advances.**
  - Immersive interaction: visual, auditory, tactile, motion…
  - LVC entities (AI-driven). Models of individual, team, organizational behaviour…
  - Commercial off-the-shelf computers and networks.
  - Generalized access to broadband.
- **Increased computation power.**
  - Fusion of cheap computation power, broadband, wireless networks and cloud-based environments.
- **New generations of learners & professionals.**
  - Students, workforce, managers and decision takers educated in IT contexts and used to the techn. change.
- **Innovations in Education and Training.**
  - The changing landscape and paradigms of education.
- **Global acceptance of simulation/gaming.**
  - A creative industry that can inform other domains.

ADVANTAGES OF USING XR SIMULATORS IN CURRENT TRAINING & EDUCATION

- **More immersion and realistic scenarios.**
- **Cognitive engagement, and emotional.**
- **Physical interaction and full-body engagement.**
- **Enhanced engagement and motivation of trainees/students.**
- **Safer practices in hazardous scenarios.**
- **Multi-user collaboration and remote training.**
- **Customizable and adaptive training.**
- **Advanced data collection and analytics.**
- **Cost-effective and scalable.**
- **Accessible simulations of complex equipment or processes.**

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XR in Simulation and Training

4. A case study.

Aspect	FFS (Full Flight Simulators)	XR-based FTD (Flight Training Device)
Hardware	Full physical cockpit, motion platform, visual system	VR/AR headsets, minimal physical hardware.
Cost	Very expensive (FFS level D may cost millions of €).	More cost-effective (off-the-shelf hardware…)
Physical Realism	High (sensations of flight, physical cockpit).	Limited (virtual controls, no motion platform…)
Training Fidelity	Extremely high. Used for real-world training credits.	High immersion experience but, often, lacking full physical interaction
Regulatory Use	Certified by civil aviation authorities for professional pilot training.	Limited certification. Mostly used for initial and supplemental training
Flexibility	Specific to aircraft type, with dedicated hardware.	Flexible, can simulate different aircrafts, instruments and environments
Scalability	Limited. It requires large facilities.	Scalable, portable, smaller footprint, easier to deploy
FlightSafety Int.		

XR in Simulation and Training

5. Challenges to the adoption of XR Technology

- **Health and safety issues. User fatigue.**
  - Using XR devices for an extended length of time can lead to motion sickness. More frequent in older VR technology.
  - The impacts of long-term use during training or operation are still being investigated.
- **Is the XR technology justified as the optimal training solution?**
  - Verify that the instructional technology available is appropriate for the training objectives, as or more effective than traditional training, safe, and cost effective.
  - This calls for a distinctive engineering where instructional approaches are applied along with the technological process.
- **Adequacy of the XR devices.**
  - e.g. the capability of the XR device(s) to meet the visual fidelity and physical requirements of the tasks.
- **Integration.**
  - Difficulty to keep pace with fast evolution: integration and interoperability, compatibility with legacy systems, etc.
- **User resistance**
  - Perceived usefulness and ease of use predict intent to use the XR solutions
  - Negative first impressions should be avoided.
- **Regulations.**
  - In some areas, e.g. pilot training, fully realizing the benefits of XR technology will require establishing XR training system requirements and a certification process.
  - In general, some type of “accreditation” will be beneficial (VV&A).

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The development of VEs for training

6. The generic project

DEFINITION	Project definition	**Needs assessment**. Background, Needs, Objectives, Stakeholders, Priorities & Constraints.
	Analysis of requirements	**Identify the application work and what can be learnt in the VE**. Task & User analysis, VTA
	Specification	**Specifications of the target VE**. XR Scenarios, Storyboarding, VTA, the XR system, Valid. Criteria
BUILDING	VE General design	**How the concept design/(storyboarding) can be realized.** Objects, layouts, UI, Functionalities…
	Resource acquisition	**Resources for modelling according to role or accuracy of objects in the VE.** 3D, sound, textures
	Detail design	**Including** dynamics/behaviors, interaction methods, cues, feedback, appearance, UI issues, etc.
	VE Programming	**Programming and integration,** using the SDK chosen.
	Verification	**For performance improvements.** Parts and the whole.
DEPLOYMENT	Deployment	**Pilot tests with users** for further improvements.
	Validation	**Form. evaluation to certify a functional and usable VE.**

VIRTUALWARE

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Adapted from: "Handbook of VE. Design, Implementation, and Applications" (Hale and Stanly ed.)

The development of VEs for training

7. Overview of the learning process

INFORMATION/ (LEARNING CONTENT)
Facts (know about…)
Concepts (Know kinds of…)
Principles (know why it happens…)
Theories, models, structures
Mental/Motor procedures (know how to…)
Metacognitive inf.
Generalities/Examples
Domain specific or general
…

SELF-SYSTEM. Decides to commit on/disengage of the learning task
Deals with the motivation and emotional regulation of learners

METACOGNITION SYSTEM. Set goals and strategies
For control and regulation of the own learning process
Based on self-knowledge and other strategic knowledge

Existing knowledge

COGNITION SYSTEM. Processes the information
e.g. Bloom's cognitive processes of remember, understand, apply, analyze…
Constraints: cognitive architecture (WM and LTM, cognitive load, etc.)

ACQUIRE	RETAIN	USE
Schemata formation Deductive/Inductive	Schemata consolidation	Schemata using (far transfer, integration)

The student/trainee

NEW TRANSFERABLE/USABLE KNOWLEDGE
- Factual knowledge
- Basic understandings
- Advanced understandings (analytical, critical…)
- Physical skills
- Intellectual skills
- Attitudes, values.
- Soft skills (social, etc.).
- Metacognitive knowledge and skills

Training that facilitates and optimizes learning
(including methods and educational technology)

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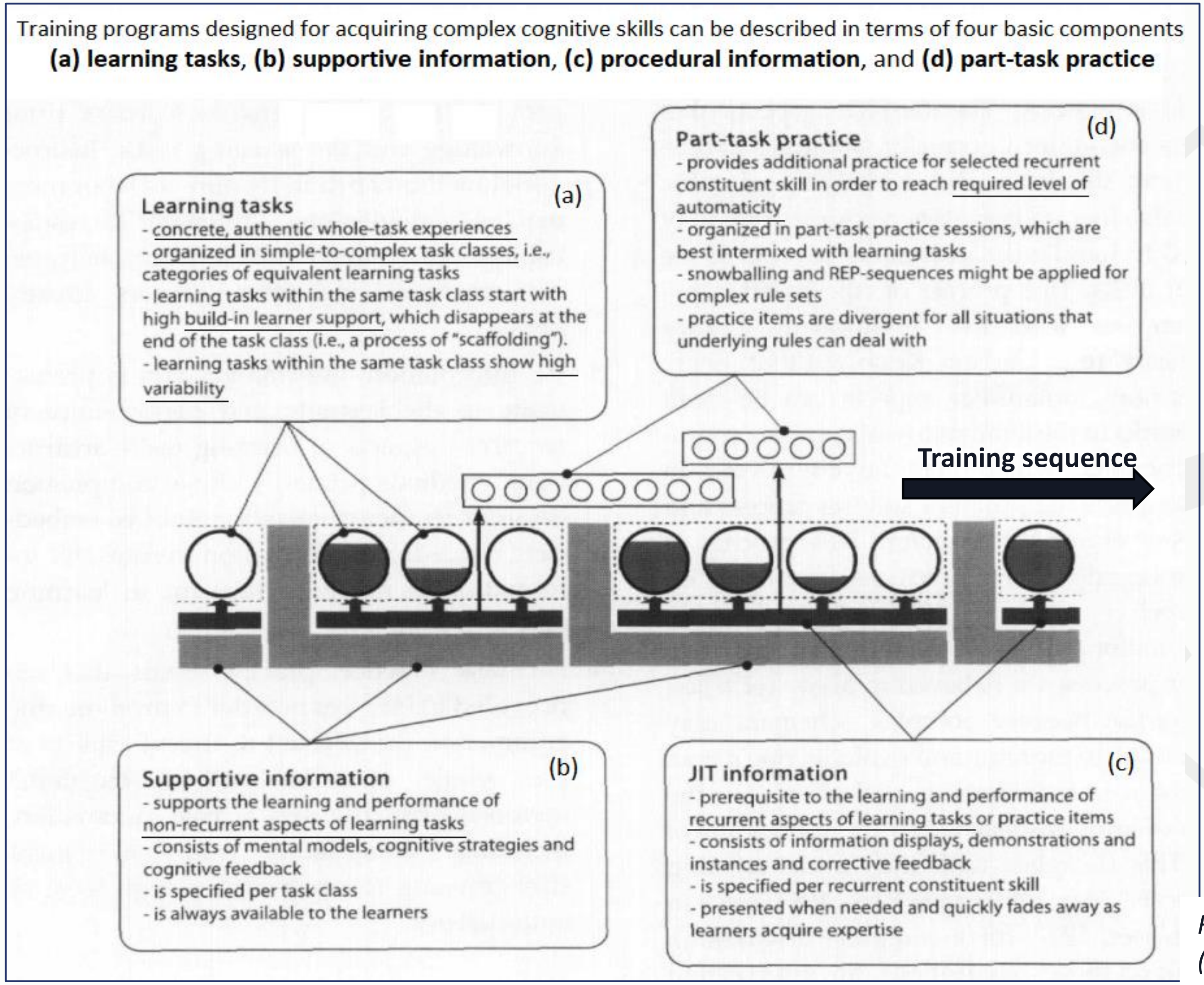
The development of VEs for training

8. Conditions of learning and types of teaching

Knowledge	Conditions and strategies to maximize learning	Example of knowledge using for transfer
Factual	*Lists of things, texts, dates, events, parts of, terminology...* Conditions/strategies: • Chunking, Organizing, Repetition, Spaced repetition, Active recall and Self-testing, Interleaved practice, Mnemonics, Contextual…	**In a car sales training:** • The trainee practices with simulated or real clients giving them (factual) information (models, major characteristics, customization possibilities, etc.) about the cars available for selling.  Questions: • Is this learning relevant? How is currently taught? • Could XR help in meeting this learning? How? • It would be comparatively effective? • Is this investment/(project) justified?
Conceptual	*Concepts, relationships (principles), theories, models, etc.* Conditions/strategies: • Examples and non-examples, Elaboration, Analogies, Inquiring, Demonstrations, Practice with classification, explanation, prediction, problem solving, decision taking, etc.	
Procedural	*Subject-specific techniques, methods, algorithms, heuristics* Conditions/strategies: • Simplifying conditions (progressive), Observe and analyze demonstrations and modelling, Relevant practice with feedback and guidance. Overlearning for automaticity. Strategic knowledge ("When", "What"…to use, etc.)	
Motor Skills	*Physical techniques highly coordinated in a domain* Conditions/strategies: • Breakdown of complex movements, Demonstration and modelling, Repetition with immediate feedback on performance. Gradual complexity and speed, Overlearning for automaticity…	
Attitudes	*Tendencies toward particular people, objects, ideas, or experiences in a domain, such as the workplace.* Conditions/strategies: • Knowing relevance, Modelling and observation of positive and negative attitudes, Cognitive, affective and behavioral elements involved, Time for habit formation, Reinforcement…	

The development of VEs for training

9. Relevance of the instructional approach

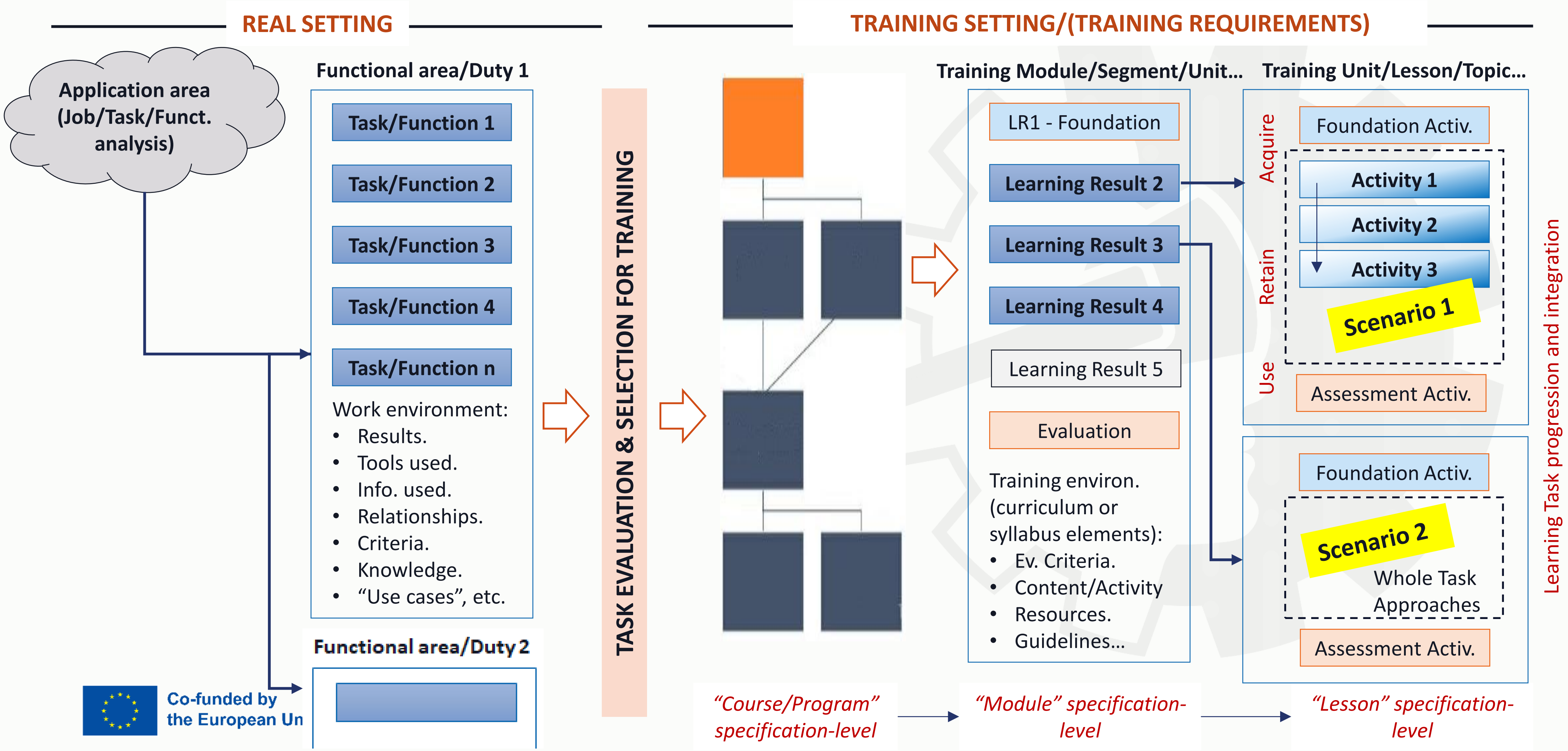


- Education systems favor competency approaches.
- Competency means the proper mobilization/(use) of KSA for a practical purpose in a domain.
- This practical using of acquired knowledge is better learnt with "whole tasks" approaches.
- Whole learning tasks are the tasks, problems, situational scenarios… that represent the real work or application area in the training setting.
- **XR simulation systems fit well with "Scenario-based" trainings where complex knowledge/(competency) is promoted (and better justify the required investments).**

Refs.: "4C/ID model"; "Ten Steps to Complex Learning" (Van Merriënboer et al.)

The development of VEs for training

10. Detail of the XR design for Scenario-based trainings



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The development of VEs for training

10. Detail of the XR design for Scenario-based trainings

SCENARIO EVAL. & SELECTION FOR XR SIMULATION

XR REQUIREMENTS AND SPECIFICATIONS

Virtual Task Analysis 1

General decisions about Tasks and Scenarios for simulation

Task/Learning Result 1	Task/Learning Result 2	Task/Learning Result n
Scenario 1	Scenario 2	Scenario n

Guidelines:
- XR technology is appropriate in this training?
- Which functions/tasks/learning objectives will be XR supported?
- To what extent? What are priorities, major constraints, etc.?
- How they will be integrated in the training framework?
- Are the training scenarios and environment appropriate for XR simulation?
- To what extent?
- With which VE solution (hard & soft for AR/VR/MR)?
- …

DECISION	OPTIONS
VR SYSTEM/SOLUTION	
Degree of *reality* desirable	Real-world replication → highly abstract
Type of presence	Egocentric, exocentric
Participants	One, few, many
Manipulation	None, click/drag, one hand, whole body…
Sensory cues	Visual, auditory, haptic…
Virtual tool provision	None, separate palette, within the VE
Mobility	Stationary, ground anchored, flying
View of scale	Close-up, arm's length, room sized…
Vision	Biocular, stereoscopic…
Viewpoint control	None, restricted, six DOF
…	…

Insights for revision of training specifications

BASIC FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS OF THE VE(s)

XR Scenario 1

XR Scenario 2

XR Scenario n

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10. Detail of the XR design for Scenario-based trainings

XR SPECIFICATIONS FOR DESIGN

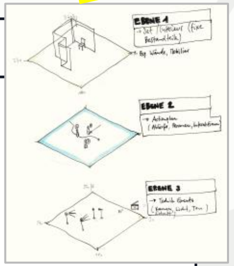
Concept design – Storyboarding of the XR Scenarios and experience → **Virtual Task Analysis 2 for details**

XR Scenario 1 **XR Scenario 2** **XR Scenario 3** **XR Scenario n**

SPECIFICATIONS FOR VE DESIGN

VR SYSTEM/SOLUTION

Visual and narrative blueprint to outline the key moments (user journey), interactions, and environments in the immersive experience: VR, AR...



Guidance (for a Text and/or Picture-based storyboard).

- **User journey** and key frames.
- Approx. **sequence** of events given an “ideal” use. Branching.
- Wire-frame models or skeletons of the **structure** of the VE.
- **Initial scenes** presented when the participant first enters the VE.
- The expected **layout** of the scene at subsequent points.
- Any narration or **instructions** within the VE: textual, aural.
- Any implicit or explicit **signs or cues** given to the participant(s). Virtual tutor.
- Images to describe the activities of the user(s). **Interactions**, sensory details.
- The **broad class of control and input devices** by which participants perform.
- Images to show the **consequences** of various actions: correct/incorrect. Feedback.
- Any **links with other software or information** resources (e.g., multimedia clips).
- A “**formal end**” to the virtual experience, e.g., when a VE Task has been completed.
- ...

VR SYSTEM/SOLUTION

Guidance

- **Detailed analysis of simulated physical tasks/operations**:
  - Task or operation breakdown.
  - Movement dynamics. Precision, angles, pressure...
  - Criteria or metrics for success.
  - Interaction metaphors: grasp, pull, desktop, etc.
  - Requirements and appropriate hardware. Motion tracking, input, haptic feedback…
- **Detailed analysis of simulated tasks/operations in procedural, cognitive (problem solving, decisional…), role play (soft skills)…Scenarios**.
- **Detailed analysis for collaborative tasks** (CVE).
  - Multiple perspectives of participants.
  - Synchronization of actions.
  - Task and role coordination.
  - Dynamic interaction and feedback…
- **Detailed analysis of virtual agents or tutors' actions**.

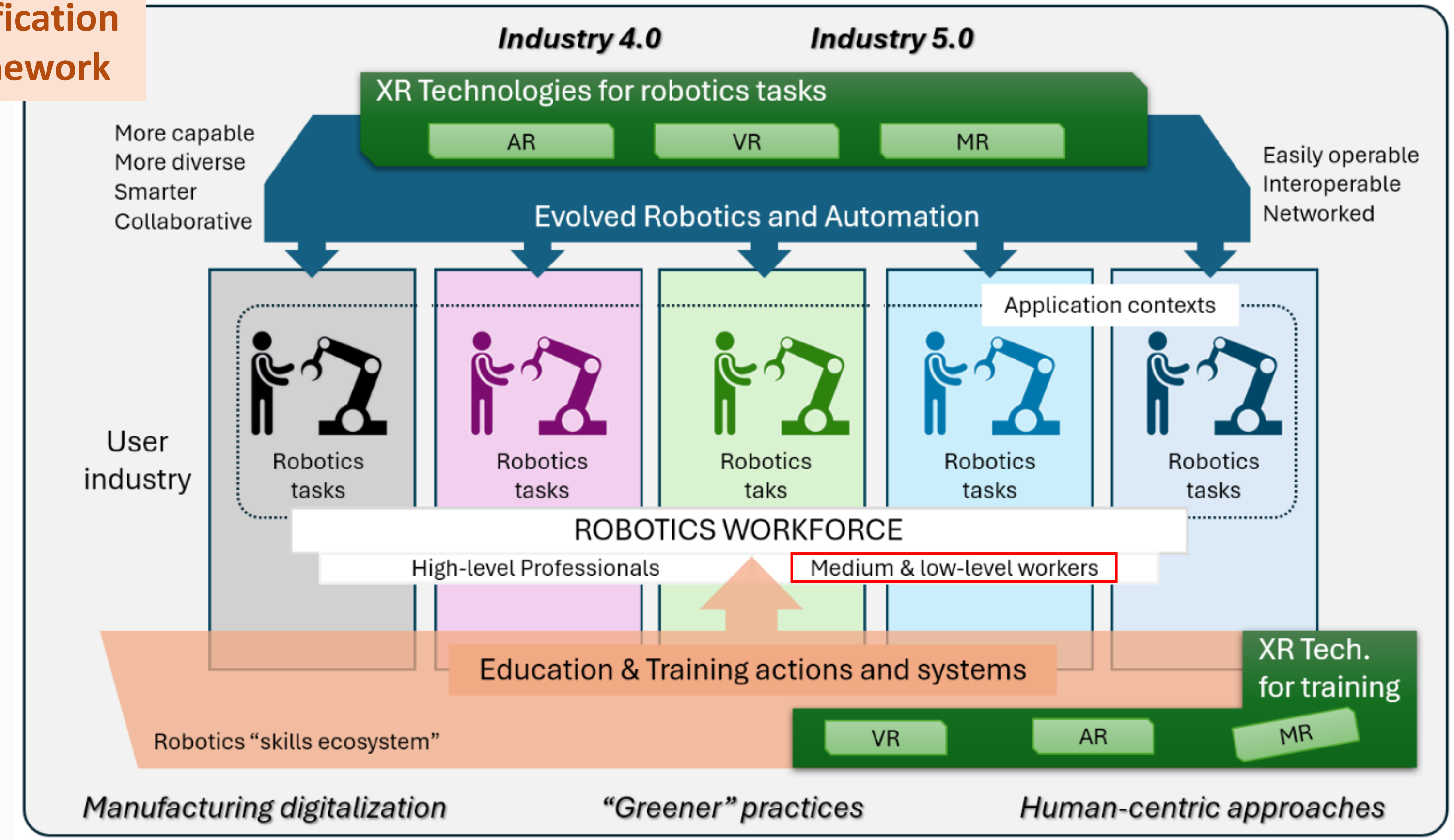
The MASTER Project

https://www.master-xr.eu/

11. MASTER objectives

- Title: Mixed reAlity ecoSystem for TEaching Robotics in manufacturing – MASTER
- Purpose: An open XR Platform for delivering rich training content on robotics and manufacturing.

Justification framework



- 4 Tech. objectives:
  - **The Open XR Platform.**

  Three main robotics use cases:
  1. **Health and safety demonstrator.**
  2. **Robotics applications programming demonstrator.**
  3. **Gaze-based interactions demonstrator.**
- 1 Educational objective:
  - **Creating XR-based robotics educational material and training.**
- 1 Industrial objective:
  - **Support SMEs and startups in XR markets (FSTP, 2OC).**

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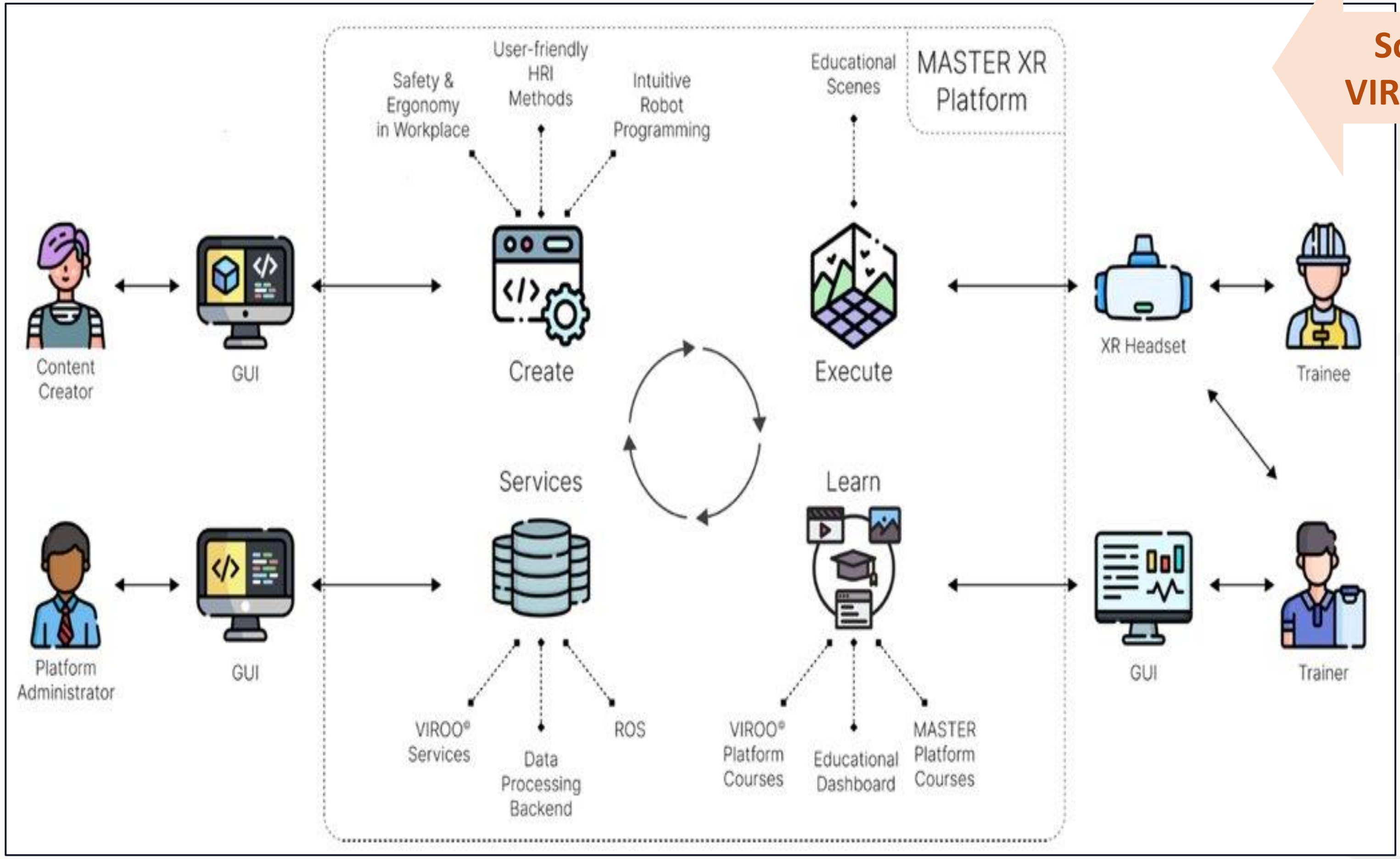
12. MASTER Open XR Platform



VIRTUALWARE

- XR Platform architecture

Solution based on the preexisting VIROO® VR Platform (VIRTUALWARE)

Basic functionalities:

- **CREATE**
  - Creation of XR scenes for robotics learning (XR Content).
- **EXECUTE**
  - Deployment of XR Content for learning.
- **SERVICES**
  - Management tasks, such as user identification, content and session hosting, permissions…
- **LEARN**
  - Integration with LMS for training management.

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13. MASTER Use cases

Health and safety demonstrator (by LMS)

- **Demonstrate that operators' safety awareness, when performing in Human-Robot collaborative workspaces, can be boosted using VE(s) with MRF included.** It includes:
  - Simulation of safety functions for HRC using VR.
  - Operators' ergonomics with decision making tools for workspace layout optimization.

Robotics programming demonstrator (by TEKNIKER)

- **Demonstrate that industry standard robot programming techniques can be simulated using XR,** focusing on:
  - Programming by Demonstration (PbD) techniques,
  - Look and Move (L&M) and other machine vision techniq.,

  as representative of codeless programming particularly useful for robotics operators and technicians.

Gaze-based interactions demonstrator (by DFKI)

- **Demonstrate how gaze-based interaction techniques used in VEs can be enhanced and applied to educational settings** (such as robotics training), focusing on:
  - Using active gaze-based interaction techniques for XR.
  - Research, model and test a passive gaze control.
  - Use AI to improve gaze-based multimodal interfaces (active & passive).

OC

MASTER OPEN XR PLATFORM
prepared for supporting advanced XR simulations

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14. MASTER Educational Use Cases (XR Scenarios for training)

Health and safety demonstrator

- XR SCENES:

1. Adaptive speed and separation monitoring based on safety zones switching.
2. Dynamic workplace adjustment tool.
3. Ergonomics assessment tool.
4. Increase operators' safety awareness.

Robotics programming demonstrator

- XR SCENES:

5. Robot end-effector approximation using Kinesthetic PbD.
6. Machine vision assisted precise positioning (L&M).
7. Programming a robot for a machine tending application.
8. Programming a robot for a line-following application.

Gaze-based interactions demonstrator

- XR SCENES:

9. Learn to Interact with Robots using your Eyes

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14. MASTER Educational Use Cases (XR Scenarios for training)

Health and safety demonstrator

- S01. Adaptive speed and separation monitoring based on safety zones switching.
  1. Introduction to the different elements of the industrial cell and robot.
  2. Introduction to the safety zones and modules.
  3. Move the robot to teach new points and visualize the zone switching in each position.
  4. Violate the different zone types within the work cell.
  5. Reset safety modules and restart robot and program.

Robotics programming demonstrator

- S05. Robot end-effector approximation using Kinesthetic PbD.
  1. Identification of DOF of the robot.
  2. Identification of FOR of the robot.
  3. Launch the system (Robot, ROS OS).
  4. Program the robot to move its end effector from its current position to a new position, near the Region of Interest.
  5. Discard the last trajectory that has been added to the robot's program.

Gaze-based interactions demonstrator

- S09. Learn to Interact with Robots using your Eyes.
  1. Introduction to mixed reality eye tracking hardware.
  2. Identification: Introduction to basic eye tracking data.
  3. Introduction to eye tracking data (advanced methods).
  4. Introduction to active gaze-based interaction (selection and manipulation).
  5. Conduct a maintenance task using gaze-based information.
  6. Loss in accuracy of the gaze signal (to force a re-calibration).

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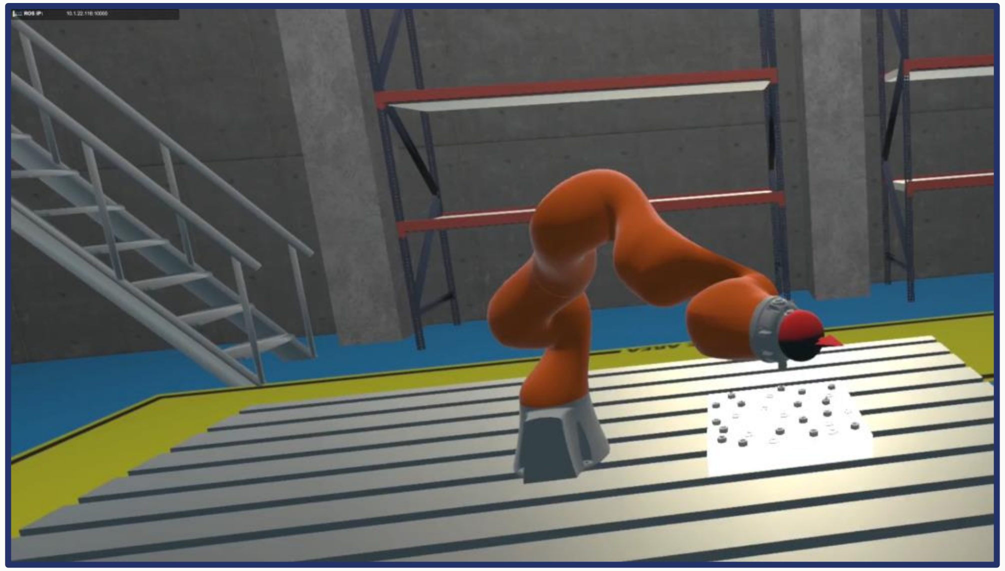
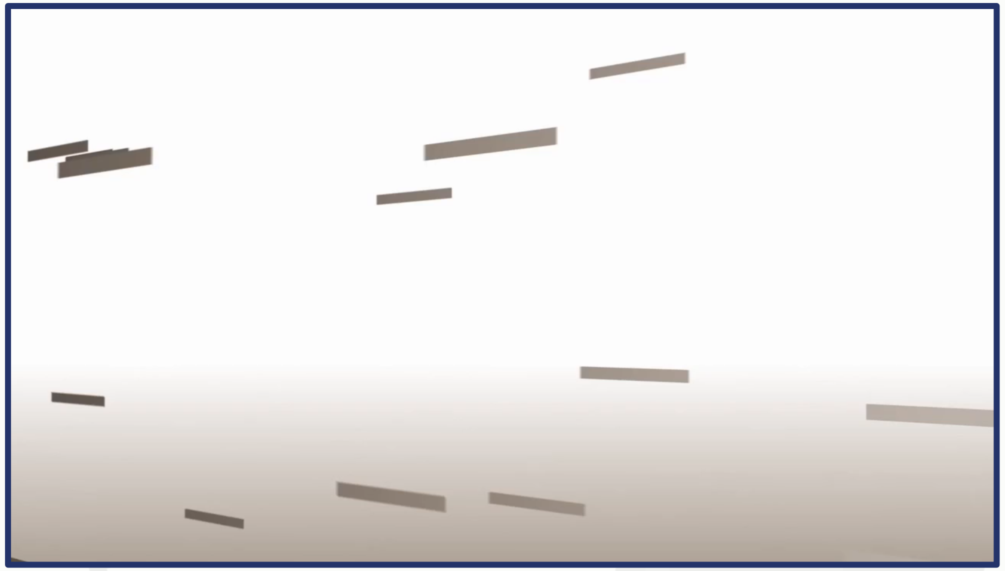
15. Examples



TEKNIKER

Robotics programming demonstrator for:
SCENARIO 05. Robot end-effector approximation using Kinesthetic PbD.

SCENARIO 06. Machine vision assisted precise positioning (L&M).



LMS

SCENARIO 01. Adaptive speed and separation monitoring based on safety zones switching.

- Ed. Use Case 3. Move the robot to teach new points and visualize the zone switching in each position.

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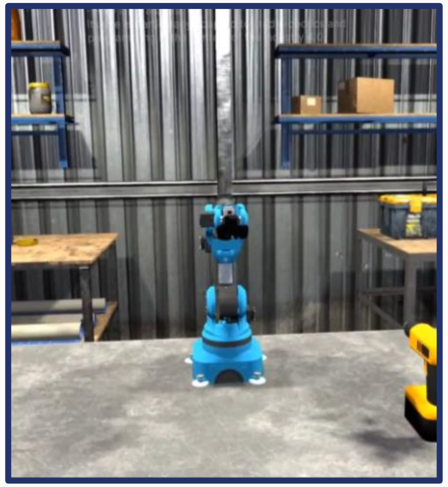
15. Examples

Navigation and object selection using gaze



Information displays and gaze-based context menus.

DFKI

SCENARIO 09. Learn to Interact with Robots using your Eyes

- Ed. Use Case 3. Introduction to active gaze-based interaction (selection and manipulation)

Practices multi-modal interaction with gaze and controller to select rotating cubes.

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Thank you

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