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Designing Virtual Innovation Labs to Support Co-Creation in Critical Infrastructures

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Abstract: This paper presents the current status of the EU-funded VILinKRITIS project, which develops a Virtual Innovation Lab (VIL) to support co-creative innovation in safety-critical process industries within the critical infrastructure domain. Addressing the challenges of distributed expertise, strict regulatory requirements, and limited effectiveness of conventional virtual collaboration, the VIL is conceptualised as an immersive, browser-based VR environment. The research follows a design science research approach and reports on the first iteration of the VIL. We present preliminary results from a mixed-methods requirements analysis which informed the identification of initial design guidelines. These guidelines emphasise a browser-based solution, trust-centred AI integration and structured user onboarding. By enhancing shared understanding and engagement through shared boundary objects, the VIL aims to overcome key limitations of virtual collaboration and foster more effective co-creative incubation processes in highly regulated industrial contexts and provide a foundation for ongoing iterative development and evaluation.

Keywords: co-creation; virtual innovation lab; critical infrastructure; innovation; shared boundary objects; virtual reality; artificial intelligence; interdisciplinary; design guidelines; design science research.

1 Introduction

Critical infrastructure (CRITIS) sectors such as chemicals and rail provide essential services to society. Their disruption can cause significant supply shortages and impact public safety, therefore they are nationally regulated by legal and sector-specific requirements – in Germany by the Federal Office for Civil Protection (BBK, no date; BMI, no date). In this context, the process industry plays an important role, with facilities handling large amounts of energy and hazardous substances and therefore operating under stringent safety and regulatory standards (Martinez, Juel and Fjelldalen, 2005). Therefore, changes to systems or processes within the CRITIS context require coordination, early stakeholder alignment, and strong risk awareness.

Innovation challenges arise less from missing ideas than from how their co-creative incubation with customers and other stakeholders is organised (Kazadi, Lievens and Mahr, 2016). In practice we observe that in safety-critical domains these challenges are further amplified by information asymmetries between specialised expert groups (e.g. functional safety, cybersecurity and operations), as well as by the need to integrate digitalisation and AI-related competencies. The relevant knowledge is often distributed across organisational units, locations and disciplines, while the time and attention of key experts are limited.

Innovation labs seek to address these challenges by providing dedicated environments and processes that support structured co-creation and experimentation with multiple stakeholders (Gryszkiewicz, Lykourentzou and Toivonen, 2017). Traditionally, business incubation has relied on co-located, service-based support in office space facilities (Bruneel *et al.*, 2012) but experts and customers are globally distributed, making in-person meetings difficult. An example of this in practice is the innovation lab of HIMA Paul Hildebrandt GmbH – himalaya. Here, experts and CRITIS customers from around the world jointly explore, co-create and validate new solutions, but face limitations in availability, travel capacity and safe and secure infrastructure.

Nowadays, virtual meeting solutions make it easy for teams to meet and collaborate across locations. While such solutions increase accessibility and flexibility, it is indicated that virtual communication can curb creative idea generation compared to in-person meetings (Brucks and Levav, 2022), potentially constraining key steps in the innovation process. Early innovation remains abstract and impedes stakeholder alignment when tangible reference points – what Star and Griesemer (1989) call shared boundary objects – are missing.

The EU-funded project VILinKRITIS addresses this co-creative incubation challenge by developing a Virtual Innovation Lab (VIL) that combines Virtual Reality (VR) and AI technologies to create an environment where co-creation can be effectively fostered in CRITIS. Here, stakeholders collaboratively visualise, discuss, and safely test ideas using shared digital boundary objects, overcoming the limitations of manual processes, location dependencies and reduced creativity due to online meeting formats. VILinKRITIS is an interdisciplinary research project involving contributors from various sectors, two academic research groups – one specialising in the sociology of labour and the other in human-AI interaction –, two companies in the CRITIS domain as well as several associated partners. One company delivers safety systems along functional safety and security solutions, while the other specialises in providing software solutions. Thus, this consortium unites expertise from multiple disciplines, including engineering, human-computer-interaction, (HCI), and social studies.

One of the objectives of the research project VILinKRITIS is to address the following question:

How can Virtual Innovation Labs be designed to enable (AI-supported) co-creative innovation in safety-critical industrial contexts?

This paper follows a design-science research approach (Hevner *et al.*, 2004) and gives insights into preliminary results from the first year of research. The objective of this research is to develop new digital working models and trustworthy technical tools to enhance co-creative incubation and collaboration across company boundaries. Since trust constitutes a key determinant of technology adoption (Bahmanziari, Pearson and Crosby, 2003) and a pivotal element in the utilisation of technology (Wagner, 1994; Luhmann, 2014), the VIL is principally designed to be low-threshold in order to foster trust and acceptance and to support early customer involvement.

The ensuing section 2 introduces the theoretical framework; section 3 describes the study design; section 4 presents preliminary findings; section 5 illustrates the current state of the VIL; and section 6 concludes the research and provides an outlook.

2 Definition & Theory

Innovation Labs, Incubation & Co-Creation

Innovation labs, incubation and co-creation are closely related concepts that frame how organisations structure and conduct collaborative innovation processes. Following Gryszkiewicz, Lykourentzou and Toivonen, an innovation lab can be defined as follows: ‘An innovation lab is a semi-autonomous organisation that engages diverse participants – on a long-term basis – in open collaboration for the purpose of creating, elaborating, and prototyping radical solutions to open-ended systemic challenges’ (2017, p. 84). Building on prior incubation research, the incubation process is conceptualised here as a structured sequence of value-adding activities and services provided within a dedicated innovation environment that supports the development and maturation of early-stage ideas or ventures until they are ready for scaling or integration into regular operations (Hackett and Dilts, 2004; Sohail, Belitski and Castro Christiansen, 2023). Within such innovation labs and incubation environments, the interaction between organisations and their stakeholders becomes central. Co-creation in this setting refers to the joint creation of value by organisations and their stakeholders, who actively participate in defining problems and shaping solutions rather than merely providing feedback (Prahalad and Ramaswamy, 2004).

The Virtual Innovation Lab as an Infrastructure for Shared Boundary Objects

Co-creation in the innovation process requires shared reference points that enable stakeholders from various disciplines to develop ideas and solutions collaboratively. To conceptualise this challenge, we draw on shared boundary object theory (Star and

Griesemer, 1989) that has its roots in sociology and has been adapted to many other research fields such as innovation management studies (Caccamo, Pittino and Tell, 2023). Boundary objects are artefacts that enable collaboration across organisational and professional boundaries by serving as shared reference points while remaining adaptable to local needs and constraints (Star and Griesemer, 1989). Their core characteristics include interpretive flexibility, support for work processes, and the ability to be weakly structured in common use while becoming more strongly structured in local application (Star, 2010). In innovation management, shared boundary objects facilitate knowledge integration and collaborative problem-solving among actors with different perspectives and expertise (Carlile, 2002; Caccamo, Pittino and Tell, 2023). This perspective is particularly relevant to the challenge addressed in VILinKRITIS, where virtual and hybrid collaboration formats often lack concrete, jointly visible artefacts and therefore fail to support early alignment and shared understanding. The VIL provides an infrastructure for boundary objects through 3D objects, virtual whiteboards, process maps and opens the opportunity for AI interfaces and collaboration tools (see next section). In this way, the VIL supports shared sensemaking, co-creation and use cases such as early validation across knowledge boundaries.

The Virtual Innovation Lab as (AI-Supported) VR Platform

The VILinKRITIS project is intended to create a VIL, for which a VR platform is being developed. Alongside augmented reality (AR) and mixed reality applications, VR forms part of extended reality (XR) software. XR refers to varying degrees of immersive media that generate virtual environments or combine them with the physical environment. VR can both represent the physical world as experienced by the human senses, as well as constituting an experiential reality of its own kind (Heinlein *et al.*, 2021; Heinlein, 2024). ‘It is a new mode of experience where various sensory and imaginary experiences are fused’ (Yoh, 2001, p. 3). For example, VR offers the possibility of visualising and manipulating processes and artefacts that cannot be physically experienced.

Parallel to the increasing accessibility of XR technologies, AI has experienced substantial growth in both research and practical application, including within XR development. A recent systematic review by Hirzle *et al.* (2023) identifies several major application areas of AI use in XR, including the generation and modification of virtual environments and objects, image enhancement, the creation of avatars and intelligent agents, as well as the prediction and interpretation of user behaviour, such as XR sickness, movement patterns and interaction preferences. AI is also increasingly used to support interaction within XR environments through gesture recognition, haptic feedback systems and intelligent virtual agents. In addition, XR spaces can serve as immersive interfaces for accessing existing web-based and generative AI applications, such as large language models (LLMs), which can be integrated via virtual web browsers. Taken together, these developments illustrate that AI-supported workflows can not only be replicated within XR environments but also enhanced through immersive, interactive, and collaborative capabilities in the context of the VIL.

3 Method

The present paper adopts the framework of design-science research, in which the design of artefacts like a VIL is understood as an iterative search process (Hevner *et al.*, 2004). Therefore, a mixed-methods approach is used to analyse the requirements for the VIL. This comprises qualitative expert interviews and a quantitative online survey of employees in the CRITIS sector and their suppliers. The surveys are complemented by various workshop formats, both to validate the findings from the surveys and to identify the most promising use cases from the results.

Qualitative Approach

Firstly, a qualitative study on the requirements for a VIL was conducted between February and April 2025. Methodologically, the approach follows the participatory and experience-based VR development framework (Heinlein *et al.*, 2021), which involves, as a first step, working in a participatory manner with the employees to clarify the requirements and objectives of the planned VR platform. Therefore, a total of 19 qualitative expert interviews (online and in-person) were conducted with 20 individuals from three companies within the consortium. The topics surveyed included innovation (understanding, practice and procedure); competencies (formal and informal); VR design (needs, concerns); the potential of AI to support VR; and support measures, particularly for the CRITIS sector. The participants work in a variety of roles within the automation technology sector, encompassing development, technical implementation, sales and training. The interviewees comprised individuals from senior management, middle management and the workforce. The interview transcripts were analysed using a deductive-inductive qualitative content analysis method (Gläser and Laudel, 2010). The second step in the participatory VR development followed in July 2025, with two online feedback workshops being conducted with 12 former interviewees, to validate the results obtained from the preceding interviews. Subsequently, over the following two months (August/September 2025), three further customer interviews were conducted to incorporate the perspective of CRITIS stakeholders. These interviewees are drawn from middle to senior management levels in the chemical industry or automation plant engineering. All 23 interviewees are located in Europe, and only 13% of them are female. The third step involved participatory use case development, which is outlined further below.

Quantitative Approach

Secondly, we conducted a quantitative online stakeholder survey (N = 56) in July and November 2025 that was informed by the results of the qualitative survey. Participants were recruited through the two industrial consortium partners, international dissemination via LinkedIn, and direct outreach at relevant industry fairs and events. The survey captured stakeholder characteristics and attitudes across several dimensions, including:

- enterprise context and current position (sector, work experience, management responsibility, FTE and degree of hybrid work)
- innovation experience (self-developed metric) and organisational innovativeness (Acar and Özşahin, 2018)
- affinity for technology interaction (Wessel, Attig and Franke, 2019)

- a knowledge test regarding XR technologies (Abbas *et al.*, 2024)
- perceived cyber risk of XR (Afroogh *et al.*, 2024) and perceived privacy risk regarding AI in VIL (Kyriakidis, Happee and de Winter, 2015), trust in AI (based on Choi and Ji, 2015), and behavioural intention to use an AI-supported VIL (Keszey, 2020).

Requirements Workshop

To systematically translate the findings from the qualitative interviews and quantitative survey into actionable design knowledge, a requirements workshop was conducted in August 2025 with stakeholders from academia, industrial consortium partners, and innovation lab experts. At the outset, participants were presented with the key results of the preceding analyses to establish a shared understanding of user needs and contextual constraints. Building on this foundation, participants derived functional and non-functional requirements from their respective perspectives, making them visible and open to discussion within the group. This collaborative process enabled the iterative refinement and consolidation of requirements, forming a structured basis for the design of the VIL artefact within the design science research process. The resulting requirements were subsequently prioritised using the MoSCoW method (Must have, Should have, Could have, Won’t have) (Ahmad *et al.*, 2017), thereby guiding the implementation of the first design iteration. The prioritised requirements inform the ongoing build-evaluate cycles of the VIL and serve as a foundation for subsequent iterations and evaluation activities.

Use Case Collection

To build the VIL specific to stakeholder needs, relevant use cases need to be identified and evaluated in terms of feasibility and desirability. The use case collection presented here builds on a synthesis of the qualitative and quantitative study results and a dedicated use case workshop, in which stakeholders mapped pain points and opportunities, conducted co-creation sessions and contributed customer interviews. Based on this process, more than 25 use cases were identified and clustered into five categories: Early Validation and Demonstration, Operational Support and Efficiency, Scenario-based Simulations, Digital Twins and System Understanding, and AI-supported Functions. In a next step, the selected use cases are subsequently implemented.

A use case that was prioritised and thus elaborated first was *Early Validation with a Customer*. First, a detailed expert interview on the individual steps of this use case was carried out, accompanied by visual process mapping in real-time to iteratively validate and refine the workflow steps. Second, the participants of the requirements workshop developed persona-based user stories from the perspectives of customer, engineering advisor, innovation expert, project manager and IT consultant. All results of the requirements analysis were summarised and given to the VR developer to take into account when developing the VIL.

4 Results

The reported findings are preliminary and part of the iterative design science process of VIL. In this section, we describe the results of the qualitative and quantitative analysis and list the identified design guidelines followed by the limitations of the analysis.

From Purpose to Process in a Modular VR Design

Empirical findings from the qualitative study underscore the interplay between the intended purpose ('what') of VR in the workplace, and the structural and procedural frameworks that govern its use ('how'). Each use case has its own purpose and its own processes, and it is necessary to determine how these should be structured to enhance the success of innovation and collaboration – like co-creative incubation in VR. The interviews revealed various potential applications for VR, such as sales, knowledge, development, collaboration, or a prototyping platform. These diverse applications reflect both the heterogeneity of the interviewees and the flexibility of the technology itself. A VR platform has the advantage that it does not have to be rigid; it can be designed and used in a flexible, modular manner, thereby enabling shared boundary objects. For instance, a sales platform in the form of a showroom is possible for the purpose of sales or consultation meetings, where, for example, digital products can also be displayed digitally (data flows, interfaces, etc.), but it can also be used as a collaboration platform on which modular elements for knowledge transfer (trainings, workshops, conferences, etc.) can be utilised, as well as a development platform for collaborative development or testing.

Multi-Level Design Challenges in VR

Having defined the scope ('what'), the design ('how') can be structured on three levels: object-related, process-related and context-related. At the object level, the focus is on the design of digital artefacts, the facilities and the atmosphere; at the process level, it concerns the design of communication channels, interaction and collaboration processes (enrolment, framework conditions, exploration level, etc.); and at the contextual level, the focus is on an organisational and intentional framework. Technology must be meaningfully integrated into existing work processes. Interfaces with systems outside VR must be ensured, documentation options created, and – of essential importance, particularly for the CRITIS sector but also for user trust – data protection and data security must be guaranteed. In terms of design, this raises various questions (c.f. Huchler, Wittal and Heinlein, 2022; Heinlein, 2024):

- What degree of embodiment is appropriate?
- What level of detail is necessary for VR and to what extent should an object be manipulable?
- How can motivating and inclusive group dynamics be generated within the virtual environment?
- How can realistic perspectives be interwoven with the representational possibilities of VR?

These questions are informed by various areas of tension that must be addressed during the VR design process. The level of detail in the environment or object design, the degree of freedom of action, and the perspective of the characters (third-person vs. first-person) may vary depending on the use case and its level of abstraction or concreteness.

Workplace Flexibility and Hybrid Collaboration Patterns in CRITIS

Looking at the results of the online survey, the final sample consisted of 56 participants after excluding incomplete responses. Most participants were located in Germany (77%), and the majority held a university degree. Only eight respondents (14.3%) were female, indicating a strong gender imbalance. In terms of professional experience, the sample is skewed towards more experienced professionals, with the largest group (41.1%) reporting more than 21 years of work experience. Average weekly working time was 39.9 hours (SD = 10.0). Participants reported spending 53.2% of their working hours in the office, 34.2% working from home, and 12.6% in other locations.

Regarding innovation activities, respondents were most strongly involved in early innovation phases, particularly idea generation and idea evaluation. In contrast, fewer participants reported frequent involvement in later stages such as prototyping, development, market implementation, and evaluation. Innovation work was distributed across individual work (39.2%), in-person collaboration (32.3%), and virtual collaboration (31.3%), highlighting the relevance of digitally supported collaboration environments.

High Technological Affinity but Limited XR Knowledge and Access

Participants in the survey reported above-average technological affinity (M = 4.51, SD = 1.01 on a 6-point scale). While familiarity with virtual reality was relatively high, knowledge of augmented reality and mixed reality concepts appeared less consistent, with frequent confusion observed in the knowledge test. The concept of the metaverse was correctly understood by 36 out of 56 respondents. Despite this general awareness, actual use of XR technologies remains limited. For augmented reality, 82% of respondents reported either never using it or using it only rarely (once or twice per year). A similar pattern was observed for virtual reality. Access to XR hardware is very limited, with only 14% reporting access to AR devices and 16% to VR headsets. These findings strongly support a desktop-first and browser-based access strategy for the VIL.

High AI Adoption but Persistent Trust Deficits

With regard to AI, more than 40% of participants reported daily use of generative AI tools. AI is already integrated into innovation-related activities such as idea generation, evaluation, prototyping, and development. Overall attitudes towards AI were positive (AI acceptance: M ≈ 6.35 on a 10-point scale), while trust in AI was comparatively lower (M = 2.73 on a 5-point scale). Perceived privacy risk in the VIL context was moderate (M = 3.47, SD = 1.66 on a 7-point scale), whereas behavioural intention to use the VIL was relatively high (M = 3.47, SD = 0.71 on a 5-point scale).

Given the limited sample size, results should be interpreted with caution. However, correlation analyses indicate that AI-related factors show the strongest associations with behavioural intention to use the VIL. In particular, AI acceptance (r = .35, p = .008) and AI trust (r = .31, p = .020) are positively related to usage intention. Perceived AI privacy risk shows a negative relationship (r = -.25, p = .060), indicating a trend effect. In contrast, demographic variables such as age (r = -.02), as well as general technological affinity (r = .14), show weaker associations.

Design Guidelines

Building on the triangulated findings from qualitative interviews, the quantitative survey, and the requirements workshop, and prioritised using the MoSCoW method, several key design guidelines for the Virtual Innovation Lab (VIL) were identified.

1. **Secure, Browser-Based, and Desktop-First Platform**: The quantitative results show very limited access to XR hardware (14% for AR and 16% for VR), which is further supported by qualitative findings. Therefore, the VIL should be implemented as a browser-based, desktop-first platform to ensure accessibility across stakeholder groups without requiring specialised hardware. In addition, both interviews and workshop results strongly emphasise the importance of security and compliance, particularly in the CRITIS context. Core requirements include EU-based hosting, end-to-end encryption, phishing-resistant multi-factor authentication, GDPR compliance, and role-based access control.
2. **Structured Onboarding and Guided User Experience**: Given the limited practical experience with XR technologies identified in both qualitative and quantitative data, an intuitive onboarding process is essential. The VIL should provide step-by-step guidance that familiarises users with functionalities, navigation, and interaction rules in a safe and self-paced manner. This directly addresses barriers to entry and supports broader adoption across heterogeneous user groups.
3. **Transparent and Trust-Centred AI Integration**: The results reveal a clear tension: While more than 40% of participants report daily use of AI and integrate it into innovation activities, trust in AI remains comparatively low and perceived privacy risks are moderate. At the same time, AI-related factors show the strongest association with behavioural intention to use the VIL. Consequently, AI integration within the VIL must be explicitly transparent and user-centric. This includes clear communication of data usage, explainable AI functionalities, and privacy-preserving design. Functional requirements include AI-supported ideation and task assistance, speech-to-text and text-to-speech capabilities, and domain-aware AI systems that incorporate both sales-related knowledge and sector-specific standards. In addition, stakeholders expressed interest in AI-based facilitation agents and chatbot functionalities to support collaboration and customer interaction.

Beyond these core requirements, several additional high-priority features were identified. These include multilingual support, clearly defined and visible interaction rules, and shared boundary objects such as whiteboards and process boards to enable co-creative work. Furthermore, the VIL should allow easy integration of external content, provide exportable meeting documentation, and support multiple use cases, including creative workshops, showrooms, makerspaces, and training environments. These requirements reflect the flexibility of the VIL identified in the qualitative analysis, where different application contexts demand varying configurations of the platform.

A further insight emerging primarily from the requirements workshops is the strong demand for social presence features. Participants highlighted the importance of visible collaborator feedback and emotional cues to support trust-building and effective co-creation in virtual environments. This aspect appears particularly relevant given the collaborative and innovation-focused use cases of the VIL but requires further validation in subsequent project phases.

Limitations

The findings should be interpreted with caution due to several limitations. The quantitative sample is relatively small (N = 56), and the qualitative sample (N = 23) originates from a small segment of the CRITIS sector, limiting generalisability. In addition, all interviewees are based in Europe, which may restrict the transferability of the results to other contexts. Finally, the strong gender imbalance (in the qualitative approach 13% female participants, and 14.3% in the quantitative approach) may limit the diversity of perspectives captured. Furthermore, the requirements analysis remains largely at an abstract level, as VR is not yet widely used (only 14% reporting access to AR devices and 16% to VR headsets). Therefore, we expect further insights from the planned user tests of the VIL with CRITIS stakeholders. The current stage of the study follows a deliberate design science research approach, which involves close, participatory development of the artefact through several iterations with CRITIS experts. The testing of the VIL will therefore be gradually expanded over the course of the project.

5 The Virtual Innovation Lab

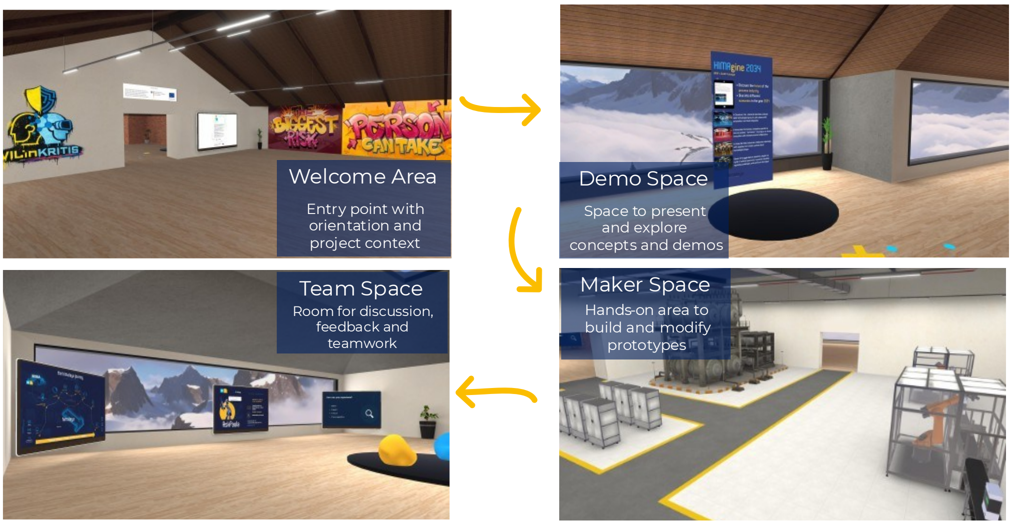

Figure 1 Current spatial architecture of the browser-based VIL, consisting of Welcome Area, Demo Space, Maker Space and Team Space.

The following describes the VIL and introduces the first implemented use case: *Early Validation with a Customer*.

Description of the Virtual Innovation Lab

Following the identified requirements and design guidelines, the VIL was developed as a desktop-first platform that can be accessed via standard web browsers. It currently consists of four interconnected functional spaces: the Welcome Area, Demo Space, Maker Space, and Team Space that are depicted in Figure 1. To ensure structured onboarding and user orientation, users receive a visual introduction to the navigation options before entering the Welcome Area. In addition to free navigation in the space, users can switch between rooms using the navigation buttons at the top of the screen (see Figure 2), which supports usability and spatial orientation in line with the requirement analysis.

The VIL supports synchronous multi-user access (up to 15 users), allowing participants to interact and communicate via real-time audio. Users can be assigned different roles, including session owner (full access and administrative rights), internal team members, and external users (typically customers) with restricted permissions.

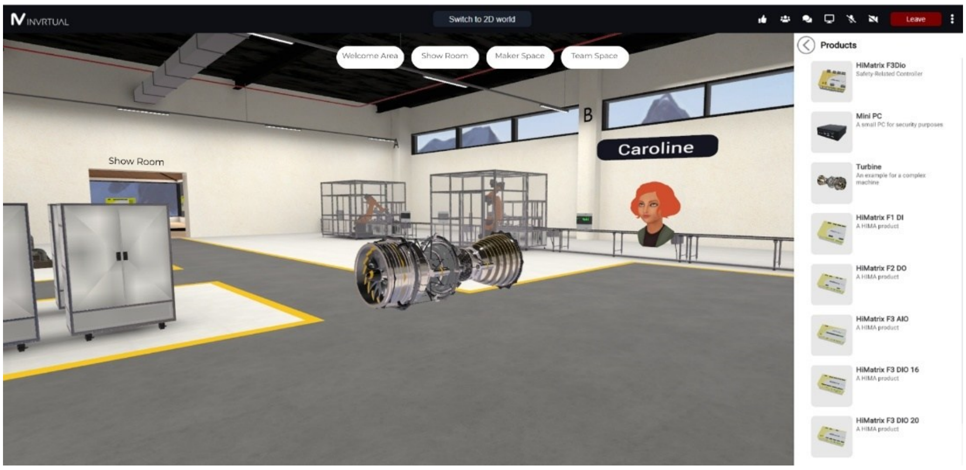

Figure 2 User perspective of collaborative innovation in the Maker Space with a turbine as an example item from the VIL product catalogue.

The **Welcome Area** functions as the central entry point and orientation space. It provides users with project context, navigation support, and onboarding information, thereby directly addressing the identified requirement for clear tutorials and orientation mechanisms. The **Demo Space** serves as a demonstrator and presentation environment in which product concepts, prototypes and partner solutions can be explored as shared visual boundary objects. 3D product visualisations and demonstrators provide jointly visible reference points that support early customer alignment and collaborative sensemaking in the co-creation process. The **Maker Space** functions as a co-creative and collaborative virtual prototyping and simulation workspace, enabling multiple stakeholders to iteratively develop and modify technical configurations, process setups and demonstrator arrangements in real time. Here, the products of the industry partner can not only be viewed as a 3D object, but they can also be combined with other modules. This directly addresses the requirement for hands-on co-creation and shared problem-solving. The **Team Space** functions as a dedicated co-creation and collaboration room for discussion, workshops, feedback processes and team-based reflection. This space particularly supports shared sensemaking through interactive artefacts such as virtual whiteboards that can show browser content and audiovisual material, process maps and discussion objects.

Additionally, users can access web-based applications via an integrated screen-like browser interface, enabling the use of external AI tools within the virtual environment. Further AI-supported functionalities are currently under development and have not yet been fully implemented. This also applies to avatar design, where additional social presence features are planned for future iterations. Across all spaces, the VIL follows an intentionally open and aesthetically coherent spatial design, inspired by the atmosphere of an alpine mountain lodge with wooden floors, ceilings, and furniture. This design choice is grounded in VR and HCI research showing that aesthetically pleasing and coherent environments enhance user experience, presence, and engagement, which in turn are closely linked to trust formation in virtual environments (Slater, 2009; Jo and Park, 2023). The current spatial architecture of the VIL operationalises the preliminary requirements by combining accessibility, orientation, collaborative boundary objects, multi-use workspaces and browser-first usability within a coherent virtual innovation infrastructure.

Use Case: Early Validation with a Customer

A regular use case that often occurs at himalaya is the use case *Early Validation with a Customer* which is why we decided to make it the first to be implemented in the VIL. In this use case the industry partner (single or team) meets with the customer. This meeting is usually conducted through in-person workshops and virtual meetings using Microsoft Powerpoint slides, process diagrams, and 2D sketches. While these artefacts support communication, they require individual cognitive translation and limit the development of a truly shared understanding.

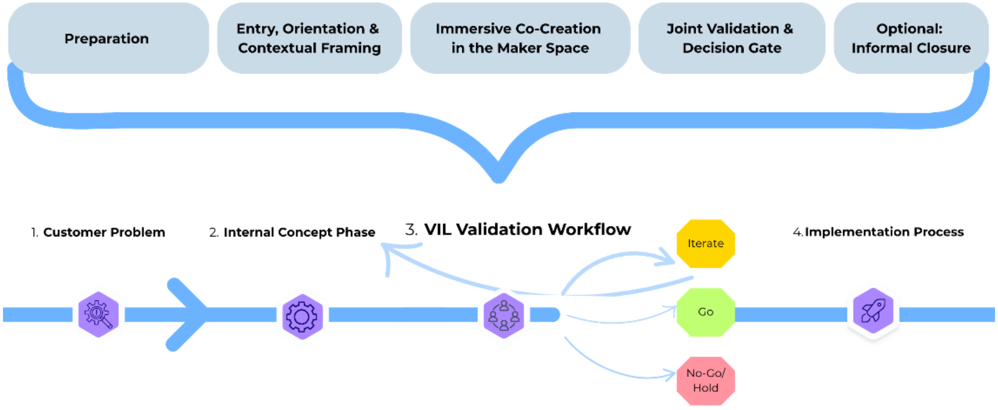

Figure 3 Process Description of Use Case *Early Validation with a Customer*.

The use case starts, as depicted in Figure 3, with the identification of a **Customer Problem** in the context of CRITIS, typically where no suitable market solution exists. This triggers an **Internal Concept Phase** involving structured problem definition, persona and scenario development, ideation, concept development, and initial customer validation through interviews, with optional iterations to refine the concept. This is followed by the **VIL Validation Workflow**. Before the meeting customers are onboarded carefully and provided with all access data and requirements, and the industry partner can prepare the Maker Space with relevant 3D models and visualisations. In a short orientation phase, stakeholders enter the immersive environment at the Welcome Area and may receive an optional Demo Space tour on the way to the Maker Space. There, customer and industry partner can collaboratively co-create, explore and adapt system and solution representations based on 3D product representation of the product catalogue in real time. The process concludes with a joint validation and decision gate for the company representative assessing desirability, feasibility and value, resulting in a go, iterate, or no-go decision to develop the solution further. In case of a go, the **Implementation Process** starts, iterations go back to the Internal Concept Phase. Optional contextual elements, such as the Demo Space or an informal exchange in the Team Space, support framing, social bonding and reflection for customer and the industry partner. Downstream development and contractual processes between the industry partner and the customer take place outside the VIL. As a next step, the presented use case will be systematically evaluated through scenario-based user testing involving realistic innovation tasks. This evaluation will assess usability, user experience, and the effectiveness of the VIL in supporting co-creative processes, thereby providing empirical insights to inform subsequent design iterations and the overall project evaluation.

6 Conclusion

This paper presented the current status and preliminary findings of the EU-funded VILinKRITIS project, which addresses the challenge of enhancing co-creative innovation in highly regulated and safety-critical industrial contexts. Building on theories of co-creation and shared boundary objects, and the requirement analysis, the paper conceptualised the VIL as an immersive and browser-first digital infrastructure that supports shared sensemaking, early stakeholder alignment and interdisciplinary knowledge integration across organisational boundaries and disciplines. The preliminary findings provide first empirically grounded insights into how VILs can be designed for co-creative innovation in CRITIS settings. These findings were translated into initial design guidelines covering onboarding and orientation mechanisms, co-creative and collaborative boundary objects, as well as modular spatial concepts for VILs in safety-critical and highly regulated environments.

Further iterations will focus on three major development streams. First, the project plans to integrate and evaluate AI-supported functionalities, including AI-based facilitation agents, domain-specific knowledge support, speech-based interfaces and additional human–AI interaction formats within the VIL. Second, the VIL will be extended to support additional use cases, including educational and simulation-based scenarios as well as operational use cases such as the documented system inspection workflow for gas warning sensors via a special interface. Third, future iterations will include systematic user testing and evaluation studies to assess usability, trust, acceptance and co-creative effectiveness across different stakeholder groups and use cases. In this sense, the VILinKRITIS project will further function as an evolving testbed for investigating how immersive environments, AI and boundary objects can jointly reshape innovation processes in critical infrastructure sectors.

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