Alliance4XR

Innovation alliance to infuse Extended Reality skills into Higher education and Vocational Training

D1.3 Mapping the challenges and good practices in knowledge flow and innovation.

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Abstract (for dissemination)	*This report, D1.3: Mapping the Challenges and Good Practices in Knowledge Flow and Innovation, provides an in-depth analysis of the integration of Extended Reality (XR) technologies across education, vocational training, and industry. As part of the Alliance4XR Erasmus+ project, the report examines key barriers to XR adoption, including knowledge gaps, cost constraints, and the need for pedagogical alignment and standardisation. Drawing on findings from a stakeholder focus group, the report identifies actionable solutions, such as tailored training programs, collaborative funding models, and the use of open-source platforms to reduce costs. It also emphasises the importance of embedding XR into curricula, fostering cross-sector partnerships, and integrating sustainability and green skills into training frameworks. Recommendations are designed to enhance accessibility, promote inclusivity, and create a standardised ecosystem for XR technologies. By addressing these challenges, the report aims to advance innovation and facilitate the widespread adoption of XR as a transformative tool for education and industry.*

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Abbreviations

Term	Explanation
XR	Extended Reality
HEI	Higher Education Institutions

VET	Vocational Education and Training
VR	Virtual Reality
AR	Augmented Reality
MR	Mixed Reality
Alliance4XR	Alliance for Extended Reality
EU	European Union
QB	Quality Board

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EXECUTIVE SUMMARY

This report provides a detailed analysis of the Alliance4XR Erasmus+ Focus Group and its key findings on the adoption of Extended Reality (XR) technologies across education, research, and industry sectors. The focus group was organised as part of the Alliance4XR project, which aims to bridge the digital skills gap and promote XR technologies in higher education institutions (HEIs) and vocational education and training (VET) centres. The insights gained will inform the development of methodologies and training materials to enhance the use of XR technologies across multiple sectors.

1 INTRODUCTION

In the realm of *Alliance4XR*, the emergence of XR technologies signifies a great advancement in facilitating profound and immersive human-digital interactions. This progress is chiefly attributed to recent strides in high-speed communication and computation, enabling unprecedented possibilities in the domains of education and training. Notably, the industry's transition towards open-source solutions, exemplified by platforms such as Unreal and Unity for XR creators, has ushered in a new era. This shift towards open-source game engines has substantially democratised the process of content creation, making the development of XR content more attainable and inclusive than ever before. As we embark on the incorporation of XR into education and training methodologies, the profound implications of these technological advancements and open-source solutions are duly acknowledged, shaping a future characterised by collaborative and accessible immersive learning experiences.

1.1 Project general objectives

The main target of the project is to design, develop and validate an innovative teaching and training approach, using XR technologies. A careful design requires a reflection on the status of the HEI, VET and key engineering sectors (structural engineering and construction, grids and energy, and maritime professions).

The investigation of the multiple uses of VR, AR and MR technologies in the field of education and training are key goals of the project. This investigation is closely related to the range of technical proficiency that you can allow for outputs, the skills of the end-users, and the financial resources available. This project will explore these aspects thereby investigating the feasibility and efficacy of XR technologies as pedagogical tools to cater to the varied needs of stakeholders in education and industry in engineering arenas.

The project implementation stage aims to be a revolutionary step, and it calls for the creation of a strong Remote & Hybrid collaboration landscape. As the educational and work environments are changing, this is the foundational framework to facilitate communication and coordination between stakeholders. This strategic emphasis on remote and hybrid models reflects the contemporary and global nature of connectivity, the urgent need for flexible learning solutions, and the necessarily deep penetration of formal education into civil society.

Ultimately, *Alliance4XR* is one example of how to foster the symbiosis of classicist educational and training methods and the frontier of new XR technologies. The idea is to work with engineering sectors and universities which will provide a scalable and flexible model for an enhanced learning experience resulting in sharing with the broader discussion on the integration of XR in education as well. The project ultimately aims to riff on this future by hacking its way into existence through research, iteration, and collaboration, where XR is woven into the fabric of pedagogy as a whole, enabling us to transcend disciplinary boundaries, enriching educational practices across disciplines of study.

1.2 Task objective

The objective of this task, as described in Work Package 1.3, is: “to engage both internal and external to the consortium stakeholders from the higher education and vocational education, research, public and business sectors in defining and discussing their views, perceptions, concerns and motivations regarding the challenges and good practices in flow and co-creation of knowledge between them. With a main focus in innovation, a focus group virtual workshop, will be organised by UCD with the support of AUTh and CEEI (estimated number of participants: 20). At least two weeks prior to the workshop, participants will be provided with the agenda of the workshop, including a detailed briefing, expected

results and their desired contribution. The workshop will be structured in three main sessions:

(i) presentation of projects results from previous implemented project tasks

(ii) co-definition of the challenges in the cooperation and knowledge transfer among the target groups

(iii) cataloguing of good practices and ideas to facilitate the target groups' sustainable cooperation and knowledge transfer collaboration."

1.3 Achievement indicators

The pre-specified achievement indicators for this task are the following:

- Number of participants: Target value is 20.

26 participants registered for the online focus group workshop, and 15 attended the event.

1.4 Structure of the document

This report is systematically organised to provide a comprehensive analysis of challenges and good practices in knowledge flow and innovation within the scope of the Alliance4XR project. The document begins with an Executive Summary, offering an overview of the key findings and objectives. This is followed by an Introduction, which contextualises the project and outlines its broader goals, such as promoting XR technologies in higher education and vocational training. The Methodology section details the design, participant selection, data collection, and data analysis processes used to gather and interpret findings from the focus group. This section also highlights the rationale for the chosen approach and the ethical considerations observed during the study. The Thematic Analysis forms the core of the report, presenting insights categorised into several themes, including knowledge gaps, cost constraints, pedagogical considerations, and standardisation. These themes are systematically analysed to provide a nuanced understanding of XR adoption challenges and opportunities. The Discussion section connects the thematic findings to the broader goals of the project, emphasising how the insights inform strategies to address market needs, foster

collaboration, and leverage use cases for scalability. The Recommendations section provides actionable strategies to overcome identified barriers, enhance XR integration, and promote sustainability.

Finally, the document includes an Appendices with supplementary materials such the focus group agenda, questions and online platform used to support the main text. This structured approach ensures clarity, accessibility, and a logical flow of information.

2 METHODOLOGY

2.1 Objective and Design

The focus group was designed as part of the Alliance4XR Erasmus+ project, aimed at exploring and addressing the challenges related to the adoption and integration of Extended Reality (XR) technologies in higher education and vocational training. The focus group followed a qualitative research methodology, chosen to facilitate in-depth exploration of participants' experiences, perceptions, and knowledge surrounding XR. According to academic best practices, focus groups are particularly effective for studying complex topics like technology adoption, where participants' interactions and discussions can reveal not only what they think, but why they think that way (Kitzinger, 1995).

Focus groups are known for their ability to generate detailed, nuanced feedback in a discussion-heavy environment, making them ideal for the explanatory research needed in this project. They allow for real-time, unfiltered responses and can be especially beneficial when exploring beliefs, thoughts, or complex phenomena (Creswell, 2009). This methodology was chosen to elicit these kinds of responses and to facilitate dynamic exchanges between participants that could uncover deeper insights.

2.2 Participant Selection

Participants were purposively selected based on their involvement in sectors relevant to XR technologies, including education, industry, and research. Purposive sampling is a common technique in focus group research, aimed at recruiting

individuals who can contribute rich, detailed perspectives due to their direct experiences with the subject matter (Creswell, 2007). The participants were grouped based on shared professional backgrounds to encourage open dialogue, as homogeneity in certain key factors (e.g., sector) can help generate more productive discussions (Morgan, 2014).

This segmentation also allowed the research to highlight variations in experiences between sectors, such as education versus industry, while maintaining focused discussions in each group.

2.3 Data Collection

The focus group was conducted online using Zoom, which enabled a geographically diverse set of participants to join. This also aligned with modern adaptations of qualitative research where virtual settings are employed to gather geographically dispersed participants efficiently (Santhosh et al., 2021). The session was semi-structured, allowing moderators to guide the discussion through key topics while enabling participants to explore these topics in their own terms.

Moderators facilitated breakout group sessions, a technique that allowed smaller, more intimate discussions on specific topics, such as knowledge gaps, standardisation, and training needs. Breakout groups help ensure that all participants have a chance to contribute and that discussions remain focused (Kitzinger, 1995)

2.4 Data Analysis

The data analysis for the A4XR focus group followed the principles of thematic analysis, a qualitative method widely used in research for identifying, analysing, and reporting patterns (themes) within data (Braun & Clarke, 2021). Thematic analysis was chosen for its flexibility in handling the rich, complex data generated from focus group discussions. This method allows researchers to make sense of participants' shared experiences, thoughts, and feelings regarding XR adoption, providing a structured approach to analysing multiple viewpoints (Clarke & Braun, 2016).

2.4.1 Transcription and Data Familiarisation

The first step in the data analysis involved transcribing the Zoom recordings of the focus group. This transcription captured both the spoken words of participants and the interactions between them, which are crucial in focus group settings where group dynamics influence the quality and depth of the discussion. Notes from the Miro boards used during the breakout sessions were also incorporated, providing visual representations of key discussion points (Santhosh et al., 2021).

Familiarising oneself with the data is a vital step in thematic analysis, as it enables the researcher to gain an initial understanding of the content, including implicit meanings and non-verbal cues (Braun & Clarke, 2006). By reading and re-reading the transcripts and reviewing the visual tools, the research team became immersed in the data, ensuring a deep comprehension of the discussions (Macnaghten & Myers, 2004).

2.4.2 Coding

Once familiar with the data, the next step was coding, which is a process of systematically identifying significant features in the data. Initial coding involved assigning descriptive labels to small segments of the text that represented important points related to XR challenges, adoption barriers, training needs, and collaboration. Codes were created manually by identifying key ideas, recurring phrases, and areas of participant agreement or disagreement (Kitzinger, 1995)

Codes such as “cost barriers,” “training gaps,” and “pedagogical alignment” emerged frequently, reflecting the participants’ concerns. These initial codes were broad, capturing everything from specific barriers to XR adoption (e.g., high costs) to general comments on XR’s potential in education.

2.4.3 Searching for Themes

In this phase, the initial codes were examined to identify broader patterns (themes) across the dataset. The research team looked for relationships between different codes and began grouping them into overarching themes. For example, codes related to “cost” were grouped under a broader theme labelled “Costs and

Resource Constraints", while codes related to the resistance from senior professionals formed the theme "Knowledge Gaps and Resistance to Adoption".

During this stage, particular attention was given to the interactions between participants, as focus groups benefit from group discussions that allow individuals to build on each other's ideas or challenge each other's perspectives (Creswell, 2007). This interactive dimension often reveals insights that might not surface in one-on-one interviews, making it essential to consider not only what was said but how it was discussed (Kitzinger, 1995).

2.4.4 Reviewing Themes

After themes were identified, the research team reviewed them to ensure they accurately reflected the data. This process involved refining and merging themes where necessary, ensuring that each theme was distinct and captured an important aspect of the data. The themes were checked against the transcripts to confirm that they were well-supported by the data (Braun & Clarke, 2021).

At this point, some themes were revised or discarded. For instance, while the initial coding had identified "language barriers" as a potential theme, upon review it was determined that it was a sub-theme of the larger issue of training and accessibility challenges. Conversely, the theme of cross-sector collaboration was strengthened as the data highlighted multiple examples of participants discussing the importance of working across different industries to advance XR adoption.

2.4.5 Defining and Naming Themes

Once the themes were finalised, they were clearly defined and named. Each theme was given a concise definition that encapsulated the main idea, allowing for easy interpretation. For example, "Costs and Resource Constraints" was defined as the financial and logistical barriers hindering XR adoption, including hardware expenses, content development costs, and ongoing maintenance issues. "Pedagogical Considerations" was defined as the need for XR to align with educational goals, ensuring technology supports, rather than overshadows, learning outcomes.

This stage is crucial in ensuring that the themes are both clear and comprehensive, making it easier to interpret the results in the context of the overall research objectives (Braun & Clarke, 2021).

2.4.6 Interpreting the Data

Finally, the themes were analysed in relation to the broader goals of the A4XR project. The interpretation went beyond simply reporting the findings; it involved connecting themes to the wider context of XR technology integration in higher education and vocational training. For example, the theme of standardisation and collaboration was linked to the need for shared XR benchmarks across sectors, reinforcing the project's objective of creating a collaborative ecosystem for XR innovation.

This stage involved drawing on the literature related to XR adoption and educational technology to frame the findings within a larger theoretical and practical context, ensuring that the insights were not only specific to the focus group but also applicable to broader XR-related challenges (Santhosh et al., 2021).

2.4.7 Presentation of Findings

The final step was the presentation of the findings, structured around the key themes. The thematic analysis results were presented in a way that connected each theme to practical solutions, helping the A4XR project move forward in designing interventions that address the identified barriers to XR adoption.

2.4.8 Ethical Considerations

Participants provided informed consent prior to the focus group, and anonymity was preserved in the reporting of results. This is a critical aspect of qualitative research, particularly in focus group settings where confidentiality may be more difficult to guarantee than in individual interviews (Macnaghten & Myers, 2004). Participants were informed of their rights, including the ability to withdraw at any time.

2.4.9 Rationale for Design Choices

The decision to use focus groups in this project was driven by their capacity to gather rich, interactive data, as well as their appropriateness for exploring complex issues such as technological adoption in educational contexts. Focus groups are particularly valuable when seeking to understand the attitudes, experiences, and barriers that may not surface in more structured interviews or surveys (Creswell, 2013). Furthermore, the inclusion of breakout sessions allowed for a more granular exploration of specific sub-topics, enabling a deeper dive into areas like cost challenges and pedagogical alignment.

3 THEMATIC ANALYSIS

3.1 Knowledge Gaps and Training Needs

The focus group highlighted a significant knowledge gap around XR technology, specifically regarding its benefits and potential applications across various sectors, including education and industry. Many participants pointed out that this gap is particularly noticeable among veteran professionals, who show resistance to adopting new XR technologies. This resistance is not only due to unfamiliarity but also because many professionals fail to see how XR can be practically integrated into their respective sectors.

Additionally, participants stressed the need for user-friendly interfaces and more discussions to promote better integration. The conversation indicated that sector-specific XR training would be more effective than generalised education, highlighting the necessity of tailored knowledge-sharing platforms.

Insights:

- Lack of contextual understanding of XR's benefits is a critical barrier to adoption.

- Tailored training and knowledge-sharing platforms are essential to bridge this gap, especially for veteran professionals resistant to change.

3.2 Costs and Resource Constraints

Another recurring issue was the high cost of XR adoption, both in terms of hardware and content management. While hardware costs are significant, participants emphasised that content maintenance is often a more substantial and persistent expense, which many organisations do not anticipate.

Additionally, participants recommended pooling resources to negotiate better deals for XR hardware and software. This approach was especially relevant for small and medium-sized enterprises that struggle with the financial burden of adopting new technologies.

Insights:

- Content generation and maintenance costs are the most significant financial burden in XR adoption, not just hardware.
- Collaboration through resource pooling is a viable solution to reduce expenses.

3.3 Pedagogical Considerations

Pedagogical alignment was another critical theme. Participants stressed the importance of ensuring that learning outcomes drive XR usage, rather than using technology for its novelty. Misalignment between technology and pedagogy can result in wasted resources and ineffective educational outcomes.

One participant shared a successful example where XR was embedded into the curriculum from the outset, ensuring that the technology was fully aligned with pedagogical goals. This example illustrates how deeper integration leads to more effective and sustainable XR adoption.

Insights:

- XR technologies must support pedagogical goals and should not be used for their own sake.
- Integrating XR into curricula from the start increases the chances of successful adoption.

3.4 Standardisation and Collaboration

Participants underscored the need for standardisation in XR to build trust and ensure reliability across various applications. The conversation highlighted the importance of EU programs and funding to set benchmarks and standards, promoting collaboration across sectors. Without standards, many organisations remain hesitant to adopt XR technology.

The need for cross-sector collaboration was another critical point. Collaborative efforts, particularly at the EU level, were seen as essential to creating benchmarks and overcoming the isolation that often characterises XR development across industries.

Insights:

- Standardisation is necessary to build trust and facilitate XR adoption.
- Collaboration across sectors and at the EU level is crucial for developing reliable benchmarks and improving cross-industry integration.

3.5 Cross-Sector and International Applications

The value of cross-sector applications and international cooperation was a major point of discussion. Participants shared examples of successful XR implementations in corporate training programs, where XR was used to help employees manage high-stress environments. These successes suggest that XR

can have significant applications across various sectors, including education and healthcare.

Furthermore, participants noted that students exposed to XR technologies during university placements often take these technologies into their industries, serving as early adopters and advocates for broader XR integration.

Insights:

- Cross-sector applications offer valuable insights that can be transferred to other industries.
- Students and new employees are important agents of change for XR adoption in the workplace.

3.6 Challenges in Technology Adoption

Several participants highlighted the challenges in technology adoption, particularly in sectors like civil engineering and maritime education, where XR usage is still emerging. Skilled personnel shortages were frequently mentioned as a barrier, compounded by the rapid pace of XR technology advancement. Moreover, language barriers were identified as an issue, as much of the available XR literature and tutorials are in English, limiting engagement in non-English speaking regions.

Insights:

- Skilled personnel shortages hinder XR adoption, especially in non-technical sectors.
- Language barriers in XR education and training materials must be addressed to expand adoption.
- Inclusivity and Access: Some participants raised concerns about the lack of inclusivity in XR experiences, particularly when users from different institutions try to collaborate. This issue often stems from technical limitations of devices like the Hololens, where users from different platforms

or institutions struggle to share experiences. Inclusivity and cross-platform functionality should be prioritised in future XR developments to enable broader collaboration and accessibility.

3.7 Conclusion

This thematic analysis of the A4XR focus group highlights both the challenges and opportunities associated with XR adoption across various sectors. Key takeaways include the need for tailored training, pedagogical alignment, and cost management strategies. Additionally, collaboration and standardisation will be essential for building trust and ensuring the widespread adoption of XR technologies. Finally, addressing language barriers and personnel shortages will further facilitate the successful integration of XR into education and industry.

4 Discussion

The findings from the focus group presented in this deliverable (D1.3) build on the insights outlined in D1.1, further refining the understanding of XR adoption challenges and identifying practices to enhance knowledge flow and innovation across higher education (HEI), vocational education (VET), and key industry sectors. Together, these reports form a cohesive narrative that aligns with the Alliance4XR project's broader objectives of bridging the skills gap and fostering collaboration through XR technologies.

4.1 Connecting Market Needs with Training Gaps

The Alliance4XR project has identified a critical disconnect between market needs and the training currently offered by higher education institutions (HEIs) and vocational education and training (VET) centres. The state-of-play outlined in D1.1 and further explored in D1.3 reveals that while XR technologies are increasingly vital for industries such as construction, maritime, and energy, existing curricula often lack the depth and specificity required to equip students and professionals with relevant, practical XR skills.

One major gap is the lack of alignment between XR training and sector-specific needs. For instance, while industries demand skilled personnel adept in using XR for safety training, virtual collaboration, and high-stakes simulations, many educational programs remain focused on theoretical concepts with limited hands-on applications. Similarly, the high costs of XR implementation, including hardware and content development, pose significant barriers for training institutions, further widening the gap between supply and demand.

D1.3 addresses these challenges by emphasising the importance of tailored training programs, informed by real-world use cases and stakeholder input. This involves creating scalable, cost-effective XR solutions that can be integrated into existing curricula while also developing faculty training programs to ensure effective delivery. Additionally, the report highlights the need for standardised frameworks to streamline XR adoption across industries, ensuring that graduates are equipped with competencies that align with evolving market demands.

By bridging this gap, the Alliance4XR project aims to foster innovation, enhance employability, and promote the sustainable integration of XR technologies into education and industry.

4.2 Enhancing Collaboration and Knowledge Flow

The Alliance4XR project places significant emphasis on fostering collaboration and improving knowledge flow to bridge the gaps between educational institutions, industries, and XR technology providers. Both D1.1 and D1.3 highlight that effective collaboration across sectors is essential for addressing the challenges of XR adoption, such as high costs, a lack of standardisation, and the scarcity of tailored training programs.

D1.1 identified the need for creating collaborative networks that connect industry and academia to co-develop solutions tailored to specific sectoral needs. For

example, industries such as construction and maritime require XR solutions that not only enhance safety and efficiency but also align with the unique operational environments of these sectors. D1.3 builds on this by emphasising the role of remote and hybrid collaboration models, which allow geographically dispersed stakeholders to co-create training materials, share resources, and exchange knowledge in real-time. These models also reduce barriers to participation, particularly for smaller institutions and organisations with limited budgets.

A significant finding from D1.3 is the importance of standardised frameworks and protocols to enhance the interoperability of XR technologies across diverse applications. Standardisation fosters trust and efficiency in collaborative efforts, ensuring that different stakeholders can work together seamlessly. The report also highlights the success of cross-sector partnerships, such as those involving HEIs and VET centres, which have demonstrated how collaborative projects can accelerate the development of XR tools and methodologies. Additionally, knowledge flow is bolstered through the integration of open-access platforms and online repositories, where stakeholders can share case studies, training materials, and best practices. These resources encourage continuous learning and innovation by making XR insights accessible to a broader audience.

By enhancing collaboration and knowledge flow, the Alliance4XR project not only addresses immediate adoption challenges but also lays the groundwork for a dynamic, interconnected ecosystem where XR technologies drive innovation and progress across education and industry.

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4.3 Leveraging Use Cases for Scalable Solutions

The Alliance4XR project emphasises the importance of real-world use cases to develop scalable solutions that address the challenges of XR adoption in education and industry. Insights from D1.1 and D1.3 demonstrate how use cases provide practical examples of XR applications, uncover barriers to implementation, and inform strategies for scaling these solutions to broader contexts.

Real-world examples highlighted in D1.1 showcase the transformative potential of XR across sectors such as maritime, construction, and energy. In the maritime sector, VR-based ship handling simulators allow trainees to practice navigation and emergency protocols in immersive, risk-free environments. In construction, AR tools enable real-time project visualisation and collaboration, improving efficiency and reducing costs. These use cases illustrate how XR can directly address industry-specific challenges, making a compelling case for its broader adoption. By demonstrating tangible benefits, such as enhanced safety and operational improvements, use cases help secure stakeholder buy-in and establish XR's relevance across diverse sectors.

Use cases are also invaluable for identifying barriers to XR implementation and proposing targeted solutions. Challenges such as high initial costs, technical integration issues, and a shortage of skilled personnel are recurring themes in D1.3. For instance, the development of bespoke XR training modules is often cost-prohibitive for many organisations. Collaborative funding models, open-source XR platforms, and partnerships between academia and industry emerge as viable strategies to reduce costs and enhance accessibility.

Scalability is a key focus in D1.3, which explores how successful implementations can extend beyond isolated contexts to achieve sector-wide or cross-sector adoption. For example, the Virtual Reality Welding Simulator in VET demonstrates how XR solutions can be adapted for different industries and educational settings. By standardising XR tools and aligning them with the specific needs of various sectors, the project creates templates for scalable deployment. Remote and hybrid collaboration models further enhance scalability by making XR resources accessible to institutions with varying levels of infrastructure.

Another critical aspect of scaling XR solutions is ensuring their alignment with pedagogical objectives. Use cases such as immersive VR modules for renewable energy training highlight how XR can support experiential learning, increase

student engagement, and improve knowledge retention. Scaling these solutions requires close collaboration among content creators, educators, and industry experts to ensure that training materials meet both academic and industry standards.

Finally, D1.3 underscores the importance of standardisation in scaling XR solutions. Developing universal protocols for content formats, evaluation metrics, and hardware interoperability helps build trust among stakeholders and ensures adaptability across various sectors and educational contexts. Standardisation fosters consistency, enabling broader adoption and making XR technologies more accessible and effective.

By leveraging use cases, the Alliance4XR project provides a clear roadmap for the scalable integration of XR technologies. This approach not only addresses the immediate barriers to adoption but also ensures that XR can sustainably transform education and industry in a rapidly evolving technological landscape.

4.4 Focus on Standardisation and Pedagogy

The integration of Extended Reality (XR) technologies into education and industry requires a balanced approach that emphasises both standardisation and alignment with pedagogical goals. The Alliance4XR project, through its deliverables D1.1 and D1.3, highlights the critical role of these two factors in ensuring that XR solutions are not only practical and scalable but also effective in achieving their intended educational and professional outcomes.

Standardisation is a recurring theme in the project's findings, as it underpins the successful adoption and interoperability of XR technologies across sectors. D1.3 underscores the need for universal frameworks that govern XR content formats, hardware compatibility, and evaluation metrics. The absence of standardisation creates significant barriers, such as limited cross-platform functionality and the inability of different institutions or industries to collaborate effectively. For example, a maritime training simulator developed by one institution may lack the

interoperability required to be integrated into another organisation's curriculum. Standardised protocols ensure that XR solutions can be shared, reused, and adapted across various contexts, fostering efficiency and cost-effectiveness.

Aligned with standardisation is the necessity for a strong pedagogical foundation. As highlighted in D1.1, XR technologies should enhance, not overshadow, educational objectives. Pedagogical alignment ensures that XR tools are purpose-driven and support active learning, engagement, and knowledge retention. For instance, virtual reality modules designed for renewable energy training provide experiential learning opportunities, allowing students to practice complex tasks in safe, controlled environments. However, without alignment to clear learning outcomes, these technologies risk becoming mere novelties rather than effective educational tools.

D1.3 builds on these insights by emphasising the need for curriculum integration. Embedding XR into the core curriculum, rather than treating it as an add-on, ensures that it becomes a fundamental part of the learning process. This requires faculty training and institutional support to equip educators with the skills and confidence needed to use XR tools effectively. Furthermore, standardised assessment methods must be developed to evaluate the impact of XR on student outcomes, ensuring that the technology genuinely enhances learning.

The project also recognises the role of collaboration in achieving standardisation and pedagogical alignment. Partnerships between academia, industry, and XR developers are essential to create tools that are both technologically robust and pedagogically sound. Such collaboration fosters the exchange of knowledge and ensures that XR solutions address real-world needs while remaining accessible to educators and learners.

In summary, the Alliance4XR project places a dual focus on standardisation and pedagogy as foundational pillars for XR adoption. Standardised frameworks enable scalability and interoperability, while pedagogical alignment ensures that XR tools

are meaningful and effective in achieving educational objectives. Together, these elements create a pathway for sustainable and impactful integration of XR technologies in education and industry.

4.5 Promoting Sustainability and Green Skills

The Alliance4XR project emphasises the integration of sustainability and green skills into XR training and education, recognising their importance for addressing climate challenges and fostering environmentally conscious practices in key sectors like energy, construction, and maritime. Deliverables D1.1 and D1.3 highlight the critical role of XR in promoting sustainable practices and equipping learners with the skills needed for a green transition.

One of the project's primary insights is that XR technologies can significantly reduce the environmental impact of traditional training methods. For example, VR-based simulations eliminate the need for physical resources like fuel, materials, or on-site equipment, which are typically required for training in fields such as construction and renewable energy. By replacing resource-intensive practices with virtual alternatives, XR contributes to lowering carbon footprints and conserving natural resources. D1.3 specifically identifies the value of XR in enabling immersive, scenario-based learning for renewable energy systems, such as wind turbine maintenance, which allows trainees to develop practical skills in a controlled, sustainable environment.

The project also focuses on embedding green skills into XR training curricula to prepare students and professionals for the demands of a sustainable economy. These skills include understanding energy efficiency, mastering renewable energy technologies, and adopting sustainable construction practices. D1.1 stresses the importance of aligning XR training with sector-specific sustainability goals, ensuring that learners are not only equipped with technical skills but also an understanding of how these skills contribute to broader environmental objectives. Furthermore, XR's ability to model and simulate real-world scenarios provides unique opportunities to teach and promote sustainability. For instance, digital

twins of energy-efficient buildings or renewable energy installations enable students to explore sustainable design principles and analyse environmental impacts in real time.

By prioritising sustainability and green skills, the Alliance4XR project aligns with global goals for climate action and sustainable development. Through innovative XR applications, the project paves the way for an environmentally responsible workforce, driving meaningful contributions to green transitions across industries.

4.6 Conclusion

The findings from D1.3 not only validate but also expand upon the insights from D1.1, offering a more comprehensive understanding of the barriers and opportunities associated with XR adoption. By focusing on practical solutions and cataloguing good practices, D1.3 bridges the gap between theoretical insights and actionable strategies, providing a strong foundation for future deliverables in the Alliance4XR project. Together, these reports emphasise the critical role of collaboration, standardisation, and targeted training in fostering innovation and equipping stakeholders with the skills needed to thrive in an XR-enabled future.

5 RECOMMENDATIONS

The integration of Extended Reality (XR) technologies into education and industry offers transformative potential, yet several barriers must be addressed to ensure effective adoption. This set of recommendations provides actionable strategies to overcome challenges such as knowledge gaps, resource constraints, and lack of standardisation. By focusing on tailored training programs, collaborative funding models, pedagogical alignment, and sustainable practices, these recommendations aim to bridge existing gaps and foster innovation. Emphasising inclusivity, accessibility, and cross-sector collaboration, they offer a roadmap to make XR technologies more accessible, effective, and impactful for diverse

stakeholders. These strategies not only address immediate barriers but also set the stage for long-term growth and integration of XR across various domains.

1. Address Knowledge Gaps and Training Needs

- Develop Tailored Training Programs: XR training programs should be designed to meet the specific needs of different sectors, such as energy, construction, and maritime. Programs should include practical applications, such as VR-based safety simulations, AR-enhanced project planning, or immersive maritime navigation training, ensuring they address real-world challenges.
- Knowledge Sharing Platforms: Create platforms that enable stakeholders to exchange insights and experiences. These platforms could include online forums, webinars, and interactive workshops focused on best practices and the integration of XR technologies into existing workflows.
- Overcoming Resistance: Focus on outreach and education for veteran professionals who may resist XR adoption. This could involve demonstrating XR's tangible benefits through pilot programs and real-world success stories.

2. Reduce Costs and Resource Constraints

- Collaborative Funding Models: Encourage partnerships between academia, industry, and public institutions to share the financial burden of XR adoption. For instance, joint ventures can pool resources for developing shared XR tools, reducing costs for individual stakeholders.
- Open-Source Platforms: Promote the use of open-source XR tools and software like Unity or Unreal Engine to lower entry barriers for smaller organisations. Open-source solutions can also foster innovation by enabling customisation to specific use cases.

3. Enhance Pedagogical Alignment

- Curriculum Integration: Embed XR into educational curricula to ensure it complements learning outcomes rather than existing as an optional add-

on. For instance, XR can be used to teach complex concepts in STEM subjects through visual simulations and interactive modules.

- Educator Training: Offer workshops and professional development programs for educators to build confidence and competence in using XR tools. This ensures they can integrate technology effectively to enhance student learning.
- Standardised Assessment Metrics: Develop evaluation frameworks to measure XR's impact on student engagement and outcomes, ensuring alignment with pedagogical goals.

4. Promote Standardisation and Collaboration

- Develop Frameworks: Establish EU-wide standards for XR content formats, hardware interoperability, and usage guidelines to facilitate collaboration and trust between stakeholders.
- Cross-Sector Collaboration: Foster partnerships between different industries, such as healthcare, energy, and education, to co-create solutions that address shared challenges. Collaborative hubs or networks can be established to streamline knowledge flow and innovation.

5. Leverage Use Cases for Scalability

- Highlight Transferable Examples: Use successful XR implementations, such as VR-based welding simulators or AR-enabled design planning tools, as templates for other sectors. These examples demonstrate how XR can address specific needs while maintaining scalability.
- Customisable Solutions: Develop XR tools that can be easily adapted across various sectors and contexts, making it easier for organisations with different objectives to implement the technology.

6. Integrate Sustainability and Green Skills

- Sustainability-Driven Training: Incorporate green skills, such as energy efficiency and sustainable construction practices, into XR training programs.

Use XR to simulate scenarios that teach learners about the environmental impacts of their decisions.

- Digital Twins and Green Models: Use digital twins and virtual environments to reduce reliance on physical materials and resources in training, minimising environmental footprints.

7. Support Inclusive and Accessible XR Development

- Language Accessibility: Translate XR training materials into multiple languages to reach a wider audience, particularly in non-English-speaking regions.
- Inclusive Design: Ensure XR tools are compatible across platforms and devices to improve accessibility for users with diverse technological resources. Tools should also accommodate users with disabilities, supporting inclusivity in training and education.

8. Expand Collaboration and Knowledge Flow

- Remote and Hybrid Models: Use remote collaboration tools to connect geographically dispersed stakeholders. XR-enabled platforms can facilitate real-time collaboration, reducing logistical barriers.
- Knowledge Repositories: Establish open-access repositories containing training materials, best practices, and case studies to encourage ongoing learning and adaptation of XR tools across industries.

9. Build Confidence Through Policy and Advocacy

- Policy Incentives: Collaborate with governments and funding bodies to create policies that incentivise XR adoption in education and industry. This could include grants, tax incentives, and recognition frameworks for institutions using XR effectively.
- Success Stories and Demonstrations: Share impactful case studies that illustrate how XR has improved training, increased efficiency, or supported sustainability goals. Such examples can inspire confidence among stakeholders and encourage wider adoption.

The recommendations outlined here provide a comprehensive approach to overcoming the challenges associated with XR adoption while maximising its potential for education and industry. Addressing knowledge gaps through targeted training and knowledge-sharing platforms ensures that stakeholders are equipped to integrate XR effectively. Collaborative funding models and open-source solutions mitigate financial barriers, while embedding XR into curricula and developing standardised assessment metrics align its use with educational goals. Promoting sustainability, inclusivity, and accessibility ensures that XR technologies support broader societal objectives, such as environmental conservation and equitable learning opportunities. Finally, fostering cross-sector collaboration and advocating for supportive policies build the trust and infrastructure needed for scalable, sustainable XR solutions. Together, these recommendations position XR as a transformative tool for enhancing education, driving innovation, and addressing global challenges.

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APPENDICES

APPENDIX A – FOCUS GROUP ADVERTISMENTS

APPENDIX B – FOCUS GROUP PARTICIPANT EMAIL

Subject: Invitation to Alliance4XR Focus Group: Knowledge Flow in XR Technologies

Dear [Participant's Name],

We are excited to confirm your participation in the **Alliance4XR Focus Group** on **"Innovative Knowledge Flow and Co-Creation in XR: Challenges and Best Practices Across Education, Research, and Industry"**, scheduled for **Monday, 23 September 2023, from 11:00 to 13:00 CET** via Zoom.

This focus group will bring together an international group of stakeholders from higher education, vocational education and training (VET), industry, and research to discuss key challenges and opportunities in the field of XR (Extended Reality) technologies. The primary objectives are to engage in a dynamic discussion, share knowledge, and collaboratively identify best practices and strategies to overcome sector-specific and cross-sectoral challenges.

Zoom Link for the Meeting:

Meeting ID: 674 2947 3300

Passcode: 874601

Focus Group Agenda and Materials

To help you prepare for the discussion, we are attaching the following materials:

1. **Alliance4XR Focus Group Agenda**
2. **Alliance4XR Project Summary Leaflet**, gives a brief overview of the Alliance4XR project.
3. **Knowledge Flow Graphic**, which explores key concepts around knowledge flow in XR.
4. **Shared Gaps Across Sectors** – This document highlights the common challenges across sectors related to XR/AR/MR adoption, including integration challenges, high costs, and training gaps.

Alliance4XR Resources and Findings

For further context, we invite you to explore the following:

- **Video Presentation**: A detailed overview of the **Alliance4XR** project's findings can be viewed here.

- **Full Project Reports**: Available on the **Alliance4XR** website, these reports offer a comprehensive view of the project's work and outcomes to date.

We look forward to your valuable contribution to this focus group and the opportunity to co-create solutions that will strengthen XR knowledge flow and innovation across sectors.

If you have any questions or require further information, please don't hesitate to reach out.

Best regards,

APPENDIX C – FOCUS GROUP AGENDA

Alliance4XR

Innovation alliance to infuse Extended Reality skills into Higher education and Vocational Training

Document Type	**Agenda**
Meeting No	**1**
Date	**23/09/2024**
Place	**Online meeting. Zoom**
Contact Person	**Marelle Rice (info@alliance4xr.eu)**

Co-funded by the European Union

Project Grant Agreement/id	101140252
Project acronym	Alliance4XR
Project full title	Innovative Knowledge Flow and Co-Creation in XR: Challenges and Best Practices Across Education, Research, and Industry
Dissemination level	Public
Date of delivery	16.09.2024
Status	Final

Disclaimer

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Agenda

Monday 23 September 2023

11:00 – 13:00 CET on Zoom

Zoom link: https://ucd-ie.zoom.us/j/67429473300?pwd=F84TFFSY7RG4yZDXHZb8hxvXhk17Ec.1
Meeting ID: 674 2947 3300
Passcode: 874601

Objectives

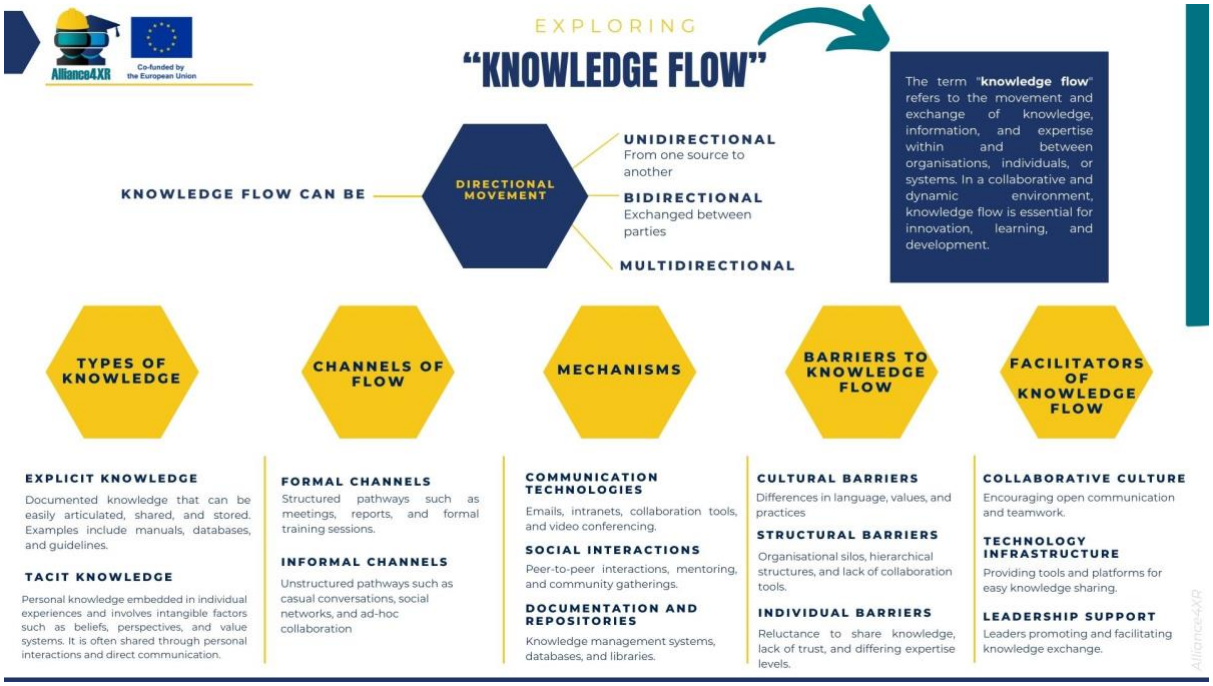
- **Engage Stakeholders**: Foster active participation from stakeholders in higher education, vocational education and training (VET), research, public, and business sectors.
- **Identify Challenges**: Define and discuss the challenges in knowledge flow and innovation among these sectors.
- **Share Best Practices**: Catalogue and share best practices that facilitate sustainable cooperation and knowledge transfer.

Expected Outcomes

- Enhanced understanding of the challenges in knowledge flow and innovation among higher education, vocational education and training (VET), research, public, and business sectors.
- A catalogue of best practices and strategies to facilitate sustainable cooperation and knowledge transfer.
- Strengthened alliances and commitment to collaborative efforts in addressing these challenges.

Time	Topic	Responsible / Presenter
11:00 - 10:10	**Introduction and Objectives** • Welcome participants. • Provide an overview of workshop objectives and agenda.	**UCD/GEOIMAGING**
11:10- 11:20	**Presentation of Project Results** • Present key findings from previous tasks. • Highlight insights relevant to knowledge flow and innovation.	**EUROXR/NOVOGIT**
11:20- 12:00	**Identifying Challenges** • Organise participants into 4 breakout groups. • Discuss specific challenges in knowledge transfer and cooperation (30 minutes). • Groups report back with summaries of their discussions (10 minutes).	**UCD / AUTH**
12:00- 12:10	BREAK	
12:10- 12:40	**Co-Defining Solutions and Best Practices** • Facilitate a brainstorming session to identify best practices and solutions. • Share successful examples and discuss strategies to overcome challenges.	**ALL**
12:40- 12:50	**Synthesis and Next Steps** • Summarise workshop outcomes. • Outline next steps	**UCD / GEOIMAGING**
12:50- 13:00	**Q&A and Closing Remarks** • Open floor for final questions or comments. • Closing remarks	**UCD / ALL**

APPENDIX D – FOCUS GROUP KNOWLEDGE FLOW



APPENDIX E – FOCUS GROUP QUESTIONS

Procedural Questions for Small Group Breakout Room Facilitation on Challenges

(30-Minute Dialogue)

Phase 1: Setting the Scene (5 Minutes)

Objective: Open the discussion by identifying key challenges in XR/AR/MR technology adoption.

1. **Opening Question: What is the biggest challenge your sector faces in integrating XR/AR/MR technologies with existing systems?**
    - *Follow-up:* Can you provide an example of a successful or unsuccessful integration attempt?

Phase 2: Exploring Specific Challenges (15 Minutes)

Objective: Dive deeper into the key challenges faced by each sector.

2. **How do the high initial costs of XR/AR/MR technology impact your sector's ability to adopt these tools?**
    - *Follow-up:* Have there been any creative approaches or partnerships that have helped mitigate these costs?
3. **How does the lack of standardisation in XR/AR/MR technologies affect your sector's progress?**
    - *Follow-up:* What types of standards or frameworks would help your sector move forward?
4. **How significant are training and knowledge gaps in your sector when it comes to adopting XR/AR/MR technologies?**
    - *Follow-up:* What types of training initiatives or professional development programs would best address these gaps?
5. **What is the biggest hurdle your sector faces in scaling XR/AR/MR technologies from pilot projects to broader implementation?**
    - *Follow-up:* What factors or resources would help your sector scale more effectively?

Phase 3: Prioritising Challenges (5 Minutes)

Objective: Encourage participants to identify which challenges are most critical to address first.

6. **Among the challenges discussed (integration, cost, standardisation, training, or scaling), which do you think is the most critical for your sector to address?**
    - *Follow-up:* Why do you believe this challenge is the most urgent?

Phase 4: Cross-Sector Reflection and Wrap-Up (5 Minutes)

Objective: Encourage reflection on cross-sector collaboration and summarise key points.

7. **How does your sector compare to others in overcoming XR/AR/MR challenges? Are there any practices from other sectors that you believe could help your own?**
    - *Follow-up:* What lessons could your sector adopt from other industries that are further along in addressing these challenges?
8. **Closing Question: What kind of external support (from industry, government, or other sectors) would most help your sector overcome these XR/AR/MR challenges?**

Facilitation Tips

- **Time Management**: Keep track of time, allowing about 3-4 minutes per question to ensure all questions are covered.
- **Encourage Participation**: Ensure all participants have the opportunity to speak, and gently guide quieter participants to share their thoughts.
- **Prioritise Key Challenges**: In Phase 3, encourage participants to focus on which challenges are the most critical and why, leading to a focused and actionable discussion.
- **Summarise**: End by summarising key challenges identified and potential opportunities for cross-sector collaboration or external support.

Procedural Questions for Solutions Focussed Whole Group Facilitation (30-Minute Dialogue)

Phase 1: Opening and Setting the Context (5 Minutes)

Objective: Quickly set the context and ensure everyone understands the purpose of the discussion.

1. **Opening Question: What is the most successful XR/AR/MR project or initiative you've been involved with or aware of in your sector?**
    - *Follow-up:* What were the key factors that made this project successful?

Phase 2: Identifying Best Practices and Solutions (10 Minutes)

Objective: Encourage participants to share specific solutions and best practices from their sectors.

2. **What best practices have emerged in your sector for integrating XR/AR/MR technologies with existing systems?**
    - *Follow-up:* Can you share a specific success story that highlights these practices?
3. **How has your sector addressed the high initial costs associated with XR/AR/MR technology adoption?**
    - *Follow-up:* Have any funding models or partnerships made a significant impact in reducing costs?
4. **What strategies have been most effective in closing knowledge and training gaps in XR/AR/MR technologies in your sector?**
    - *Follow-up:* Which training methods (e.g., workshops, hands-on sessions, e-learning) have worked best?

Phase 3: Exploring Collaboration and Scaling (10 Minutes)

Objective: Discuss cross-sector collaboration, scaling strategies, and financial models.

5. **How has your sector managed to scale XR/AR/MR technologies from pilot projects to broader real-world applications?**
    - *Follow-up:* What factors were critical in making these scaling efforts successful?
6. **What role has cross-sector collaboration played in overcoming XR/AR/MR challenges?**
    - *Follow-up:* How might partnerships with other sectors or organisations help accelerate success in your sector?
7. **What funding models or cost-benefit strategies have been effective in supporting XR/AR/MR technologies in your sector?**

- *Follow-up:* How have these financial models supported long-term sustainability?

Phase 4: Future Opportunities and Next Steps (5 Minutes)

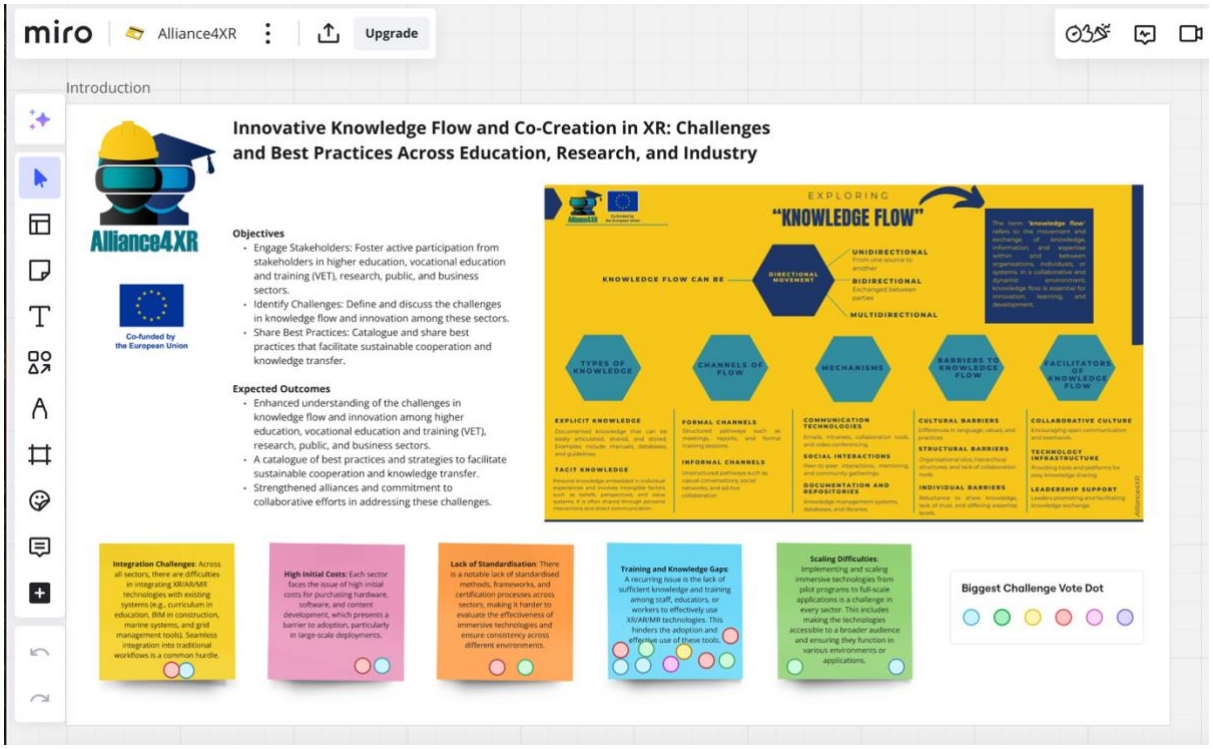
Objective: Identify key opportunities and action steps for continued progress.

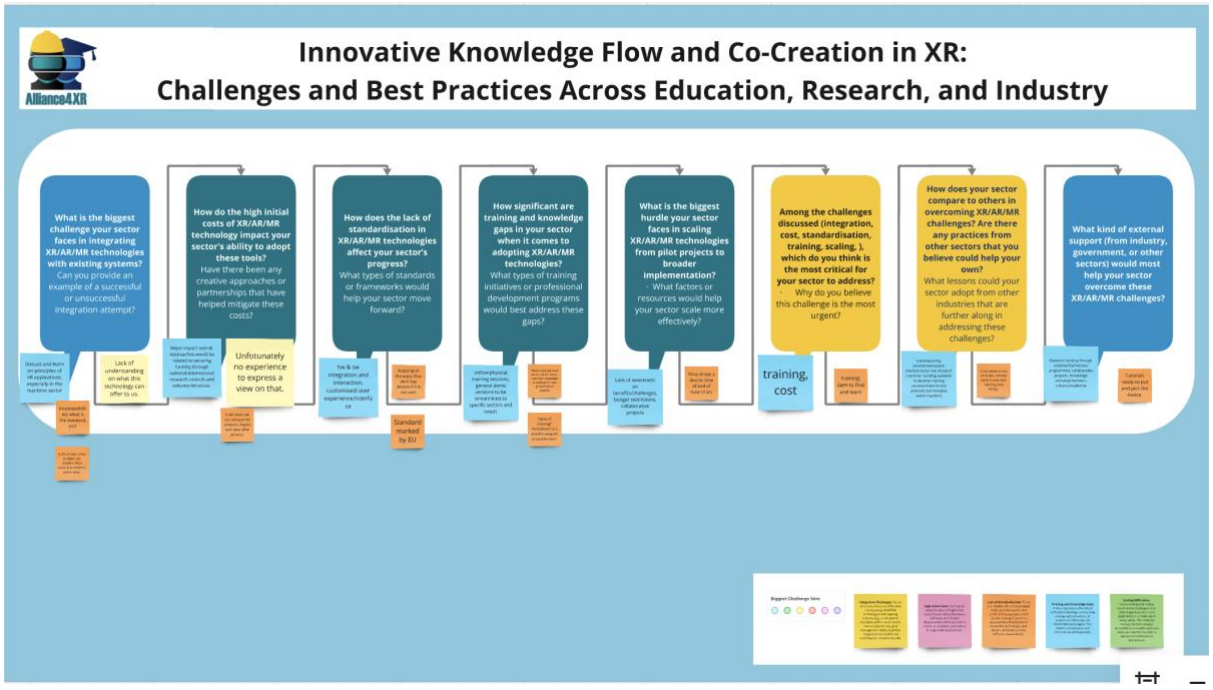
8. **Looking forward, what are the biggest opportunities for improvement or innovation with XR/AR/MR technologies in your sector?**
    - *Follow-up:* What steps can be taken now to prepare for these future advancements?
9. **Closing Question: What are the most critical next steps your sector should take to ensure the long-term success of XR/AR/MR technologies?**
    - *Follow-up:* What resources or partnerships would be most helpful in supporting these next steps?

Facilitation

- **Time Management**: Allow approximately 1-2 minutes per response and guide the group to stay on topic to ensure all questions are covered.
- **Balance Participation**: Encourage participation from all sectors and ensure everyone has the opportunity to speak.
- **Follow-Up Flexibility**: Use follow-up questions as needed to dig deeper, but avoid getting too detailed if time is tight.
- **Recap & Next Steps**: At the end, briefly recap the key points and ask participants to reflect on how they might apply what they've learned.

APPENDIX F – FOCUS GROUP MIRO BOARD EXAMPLE





Solutions Focussed Whole Group Discussion