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Report

Managing Extended Reality Initiatives in Organisations

A manager´s guide to XR

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ABSTRACT
This report is intended as a practical introduction guide to help organisations with the process of trying extended reality- technologies by introducing the technologies, giving examples of what these technologies can be used for and providing two tools for managing XR initiatives in organisations. It contains a brief definition and provides examples of use and outlines a model for organisations to use when introducing XR technologies in their organisation. In the appendixes a list of current XR systems and development systems are provided to help users understand the practical differences and better navigate in the jungle of equipment offered.

The report originated from the "Nullfeil i Autonome produksjonssystem" (NAP) project where technology was developed for zero defect manufacturing within the fields of automation and autonomy. Various technological systems were analysed as to how they could be used to provide information to the shop floor operators, but in the end XR was not chosen as the preferred tool in that particular project. However, an effort on analysing XR systems had been done and this report was finalised as part of our strategic effort for the "Digitally Enhanced Worker "at SINTEF.

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1 Introduction

This guide is intended as a practical introduction guide for managing extended reality initiatives in organisations. Extended Reality (XR) is an umbrella term that encompasses augmented reality (AR), mixed reality (MR), virtual reality (VR), and other forms of alternate, expanded, or immersive reality applications, including those not yet invented. There is a lot of information available on new XR systems and benefits of using XR, but many find it challenging to find guidelines for how to manage the processes of developing, testing and implementing XR in their organisations. That is the reason for writing this guide where the focus is on AR, VR and MR that exists and are being used in the market to this day.

The purpose and scope of this guide is to give an introduction of these XR- technologies, how these technologies are being used in organisations and some guidelines for how to manage XR initiatives in organisations. This guide is intended as a practical guide and is divided into three parts. An introduction to what extended realities, what you can use XR for and how to manage XR-initiatives.

Our description of XR activities are taken from our own experiences, research articles, the internet and other non-scientific reports. The last chapter about how to get started with XR in organisations is based upon our many years of experience with XR and gives an overview of evaluations and reflections that we think is important that you take into considerations when managing XR-initiatives in an organisation.

If you are new to the field, we recommend that you start at the beginning. However, the parts are independent so you can go directly to the chapter you feel is most relevant for you. There are four appendices attached to give an overview of terms and definitions, XR systems, development platforms and content applications.

2 What is extended reality (XR)

Extended Reality (XR) is an umbrella term that encompasses augmented reality (AR), mixed reality (MR), virtual reality (VR), and other forms of alternate, expanded, or immersive reality applications, including those not yet invented[1]. To get a thorough understanding of XR that fuses the three terms augmented, mixed and virtual reality, a short description of each of them individually is needed. Figure 1 below illustrates where each technology operates in the reality – virtuality axis.

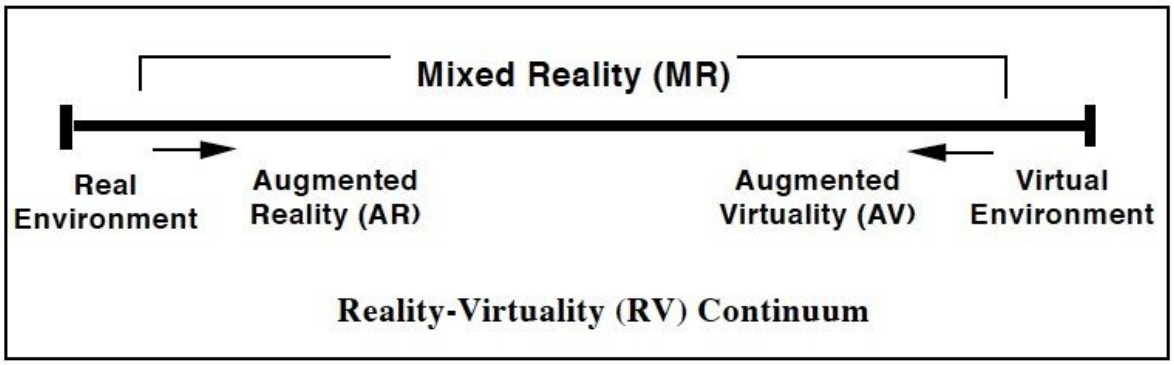


Figure 1. The Reality - Virtuality (RV) Continuum from Milgram,Takemura, Utsumi & Kishino (1995).

2.1 Virtual Reality

VR is a technology that immerses humans into a fully digital reality that is entirely different from a real one or that replicates reality through a headset or surrounding display. VR is not a new technology, one of the first known VR machines is the Sensorama from 1957 and already in 1961 experimenting with HMDs with one screen to each eye started[2]. Although this was not virtual reality due to it lacking a computer simulation, it was the first step for the evolution of VR HMDs. What's new is the development of more user-friendly VR headsets that are cheaper and more accessible for consumers than before[3]. Enabled by specific headsets, virtual reality provides an environment with realistic images and sounds. Two key concepts of VR theory are immersion and presence. Immersion describes the experience of using immersive technology that exchanges sensory input from reality with digitally generated sensory input[4] . The degree of immersion is an objective property of a system, while presence is the human response to the system and expresses the sense of 'being there' in the virtual environment [5]. You can distinguish between desktop virtual reality where the virtual reality environments are delivered via a computer monitor and mobile device screen (tablet or smart phone), and immersive virtual reality delivered via HMDs that give the user the impression that they are in the virtual environment. Immersion is when the properties of a technology are designed to allow the user to feel a sense of presence and that she/he is present in the virtual environment.

[1] XR Association (.n.y).
[2] Virtual Reality Society (n.y)
[3] Bezegová.et al, 2017.
[4] Jensen & Konradsen, 2018.
[5] Sanchez-Vives & Slater, 2005.

The interaction in a desktop virtual environment is by using a keyboard, mouse, touch screen, joystick or other gaming device. Immersive virtual reality is also called virtual reality as HMDS are now more prevalent and can range from a passive experience where you look around to more interactive experiences where the user can navigate around the environment and manipulate virtual objects. Highly immersive virtual reality is delivered via a head mounted display (HMD) in which the user has a high degree of agency and ability to act by manipulating virtual objects, interacting with other users and computer-generated non-player characters, and having the ability to create within the virtual environment[6].


VR offers new opportunities for the development of innovative clinical research, assessment, and intervention tools and is being increasingly regarded as providing innovative options for targeting the cognitive, psychological, motor, and functional impairments that result from various clinical health conditions. VR allows for precise presentation and control of stimuli within dynamic multisensory 3-D computer generated simulations as well as providing advanced methods for capturing and quantifying behavioural responses[7]. VR can transform and innovating traditional sectors such as manufacturing industries, construction and healthcare, and it can revolutionize education, culture, travelling and entertainment[8]. Organizations are using Oculus VR headsets to increase productivity, reduce training costs, enhance collaboration, and more.

The use of virtual reality (VR) in education can be considered as one of the natural evolutions of computer-assisted instruction (CAI) or computer-based training (CBT). Some learning benefits of VR are spatial knowledge presentation, experiential learning, engagement, contextual learning and collaborative learning[9],[10]. VR has unique properties known as affordances that can offer teachers and students unique learning experiences. These include the ability to have experience that might be impractical, impossible or unsafe in real life, manipulate size and scale to improve understanding or perspective swapping.

[6] Southgate et al, 2019.
[7] Rizzo, Koenig & Talbot, 2019
[8] Bezegová et al, 2017
[9] Fowler, 2015
[10] Pantelidis, 2009.

2.2 Augmented reality

Augmented reality (AR) can be described as a set of technologies that superimposes digital data and images on the physical world. It refers to a real-world environment enhanced with computer-generated information such as sound, video or graphics. Unlike VR, augmented reality is not a world that is entirely different from a real one. With AR you add some attributes but do not change your reality completely. Some vivid examples of its implementations are the Pokemon Go game, SnapChat with its filter add-ons and rear view cameras on cars. Smartphone AR is where an augmented environment layers virtual content where digital objects and information are layered onto a real-world image captured from a device's camera. A rendered virtual image can be overlaid on top of the image obtained from the device's camera, making it appear as if the virtual content is part of the real world[11]. With headset AR the user puts on head-mounted display devices like Hololens, Magic Leap or smartglasses that provide a simulated visual environment through physical display optic lenses, allowing the user to see both a digital display and the world through the glasses.

AR seems on the verge of breaking out into something big, and 2020 is predicted to be a huge year for consumer AR. Already in 2019 there has been a series of massive announcements from tech giants, including roll-outs of new features or products from Facebook, Snapchat, Google, Apple, Huawei and Youtube[12]. Augmented reality is reaching a mature state according to Gartner, it is no more an "emerging" technology, but it has graduated as a mature one. Gartner Hype Cycle 2019 shows the current status of emerging technologies from when they become visible to the market to when they become usable and profitable. In the Gartner Hype Cycle 2019, there is no longer mention of AR[13]. This indicates that for Gartner, AR and VR are now both mature technologies

AR has the potential to motivate and engage students, especially in learning abstract or theoretical knowledge, or allowing students to experience what may be unsafe or infeasible in real life; AR lends itself to collaborative learning, especially as a training tool[14]. AR- technology can also connect workers with the digital environment, and industrial augmented reality (IAR) is one of the key pillars of the industrial digitalisation concepts. It is important to make sure that information reaches its destination in a way that is perceivable by the end user, facilitating operators to perform operations and/or make decisions. During the last few years, augmented reality technology (AR) has arisen in manufacturing that supports vivid depiction of information, using animations, 3 D geometries, and text[15].

[11] XR Association, n.y.
[12] Hadwick, 2019 - 2020
[13] Gartner, 2019.
[14] Southgate et al, 2019.
[15] Mourtzis et al, 2017,

Although VR and AR are different, they share common processes and technologies, such as audio software and data processing, and tend to concentrate in the same business and research worlds, hence creating overlapping ecosystems. Interestingly VR & AR ecosystems are closely related to the industry of artificial intelligence (AI) and it is important to be aware of the synergies amongst these three high- tech industry and their closely related ecosystems[16].

2.3 Mixed Reality

Mixed Reality (MR) is sometimes referred to as hybrid reality. It is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. It means placing new imagery within a real space in such a way that the new imagery can interact, to an extent, with what is real in the physical world we know. The term Mixed Reality is closely linked to AR, and in the past the term MR used to mean AR. This however changed when HoloLens by Microsoft came to the market. The main difference involved the key characteristic of MR which is that the synthetic content and the real-world content can react to each other in real time.

[16] Bezegová et al, 2017.

3 What is XR being used for?

Immersive experiences are changing the way people connect with information, experiences, and each other. Immersive technologies and XR- technology are rapidly evolving and XR professionals are chasing the growth in supporting enterprises and shifting focus to providing enterprises with solutions. XR have the potential to transform the way we work, communicate, and experience things. Many sectors are seeing the value of investing in XR capabilities, particularly education, architecture, engineering, construction, manufacturing and healthcare field. Many can realise strong returns from deploying XR in areas like design, prototype, collaborating on projects and training and education. From replacing or supplementing training simulators, to visualize abstract concepts, create learning scenarios beyond the classroom, XR technologies have huge potential in the education and training space and in sectors where visualization often is required, training burdens can be high, product design can be complicated and costs to materialize projects can be expensive[17].

XR is also changing the way people work and is driving industrial innovation.
The manufacturing industry is regarded as one of the most mature in its adoption of XR devices. Industry 4.0 dictates that data need to be distributed very fast while ensuring that data are securely transmitted. According to an operator 4.0 typology that depicts how the Industry 4.0 technologies can assist operators to become smarter operators' in their future factory workplaces, list some of the interactions that they have[18]:

- Operator + Exoskeleton = Super-Strength Operator (physical interaction)
- Operator +Wearable Tracker = Healthy Operator (physical and cognitive interaction)
- Operator + Intelligent Personal Assistant = Smarter Operator (cognitive interaction)
- Operator + Collaborative Robot = Collaborative Operator (physical interaction)
- Operator + Social Networks = Social Operator (cognitive interaction)
- Operator + Big Data Analytics = Analytical Operator (cognitive interaction)
- Operator + Virtual Reality = Virtual Operator (cognitive interaction)
- Operator + Augmented Reality = Augmented Operator (cognitive interaction).

When it comes to research within the field, it seems like the most popular research subjects among European academics are industrial design, healthcare and training, and simulation. According to a survey based on 761 XR professionals, XR is mostly used for product design and prototyping, workforce/ project collaboration, educational learning, training/worker guidance, sales and marketing/ external communication and within manufacturing in businesses[19]. See the table for details below.

Table 1 What XR is mostly used for based on a survey of 761 XR professionals

Technology	*Product design and prototyping*	*Workforce, project collaboration*	*Educational learning, training, worker guidance*	*Sales, marketing, external communications*	*Manufacturing*
VR	96,3 %	93.4 %	89,7%	84,2 %	81,1%
AR/MR	46, 3%	47,5 %	54,6%	56,6%	51.4 %

[17] Hadwick, 2019 - 2020
[18]Romero et al, 2016.
[19] Hadwick, 2019 - 2020

A statistic depicts the forecast breakdown of the augmented and mixed reality software market in 2022. By that time, it is predicted that the video games segment will represent 34 % of the augmented and mixed reality software market, which is forecast to reach 80 billion U.S. dollars that year. Healthcare will represent 15 %, engineering 14 %, live events 12 %, video entertainment 9 %, real estate 7 %, retail 5 % and military 4 %[20].

3.1 Examples from organisations

To give some more ideas and understanding of how XR can be used in organisations, examples from both research and practical use of the technology within the areas educational learning, immersive training, healthcare and manufacturing is provided in the table below.

Context	Objective	Tech-nology	Who	Source (articles, websites etc.)
Educational learning	Mathematical assignments	VR	VR Education	https://vreducation.no/en
Educational learning	Working memory training in virtual reality classrooms for children	VR	Coleman et al - research	https://doi.org/10.3389/fpsyg.2019.01851
Learning and training	Training Security Critical Agents	AR/VR	16 partners from 10 EU member states	https://www.target-h2020.eu/
Learning and training	Multi-agent counter terrorist training	VR/MR	14 participants from 7 countries	https://cordis.europa.eu/project/id/653590
Learning and training	Training executive brain functions to enhance police officers' level of mental preparedness for crisis situations	VR	The police district in Trøndelag in Norway	https://www.politiforum.no/artikler/trening-med-vr-briller-kan-bli-en-del-av-politiets-framtid/387443
Learning and training	Firearms training on a virtual shooting track with a real police firearm	MR	The police district in Trøndelag	https://www.politiforum.no/artikler/slik-kan-den-virtuelle-verden-bli-politiets-ovingsarena/459490
Learning and training	Providing more empathy and better customer experiences	VR	Farmers Insurance	https://www.forbes.com/sites/jeffkaufliin/2017/11/05/farmers-insurance-is-using-virtual-

[20] Statista Research Department, 2016

				reality-to-transform-its-employee-training/#780c359c3ee3
Learning and training	Immerse people in the shipment process that is where VR really works for their business.		DHL Express	https://business.oculus.com/
Learning and training	Doctors and nurses training for COVID-19 pandemic using VR technology	VR	Oxford Medical Simulation	https://www.techrepublic.com/article/free-medical-vr-training-system-being-offered-to-help-combat-the-covid-19-pandemic/?fbclid=IwAR1iUVMsAUW2axKsnUs7mVMVwPvhjZlwxp5qbk5FSbaUz3FOOmpLPVVdlVA
Learning and training	Virtual Reality Tool to Teach Surgical Technique for Tibial Shaft Fracture Intramedullary Nailing	VR	David Geffen School of Medicine at the University of California Los Angeles (UCLA).	https://medicalsimulation.training/surgical/osso-vr-validation-study/
Healthcare	Mental health symptoms and neuropsychological functioning, cognitions, emotions and behaviour		Kings College in London	https://www.kcl.ac.uk/ioppn/depts/psychology/research/ResearchGroupings/VRRG/About-the-Virtual-Reality-Research-Group
Healthcare	Heart surgery planning	MR	Research article.	Brun, Bugge, Suther, Birkeland, Kumar, Pelanis & Elle.(2018) Mixed reality holograms for heart surgery planning: first user experience in congenital heart

				disease. European Heart Journal Cardiovascular Imaging (2019) 20, 883–888.doi:10.1093/ehjci/jey184
Healthcare	Improved spatial understanding of liver anatomy	MR	Research article.	Egidijus Pelanis, Rahul P. Kumar, Davit L. Aghayan, Rafael Palomar, Åsmund, A. Fretland, Henrik Brun, Ole Jakob, Elle & Bjørn Edwin (2019): Use of mixed reality for improved spatial understanding of liver anatomy, Minimally Invasive Therapy & Allied Technologies, DOI:10.1080/13645706.2019.1616558
Industry	Simulation based operator training	VR	Komatsu	https://pbeinc.com/news/komatsu-worksite-vr-simulator-construction-machine-training-for-the-21st-century/
Industry	Increase worker productivity, improve quality and error reduction	AR	GE Aviation	https://upskill.io/resources/blog/getting-torque-just-right-skylight-save-millions/
Industry	An integrated industrial AR system to increase manufacturing productivity.	AR	KIT-AR	https://www.kit-ar.com/

4 Managing XR initiatives in organisations (MaXIt)

In this chapter we describe The MaXIt model that consist of guidelines based upon our many years of experience with XR projects in organisations. We also present two tools to use when managing these processes: *The Four Phases* and *15 steps to get you started*.

MaXIt gives an overview of evaluations and reflections that we think is important to take into considerations when managing XR- initiatives in an organisation. It is important to emphasize that this model, like all models, is a simplification of reality that should be used as a tool that is adjusted and adapted to its context. The objective is not for it to be used as a fixed method, but rather provide for important steps to facilitate for reflections and answers that will guide you in the process of managing XR initiatives in your organisation.

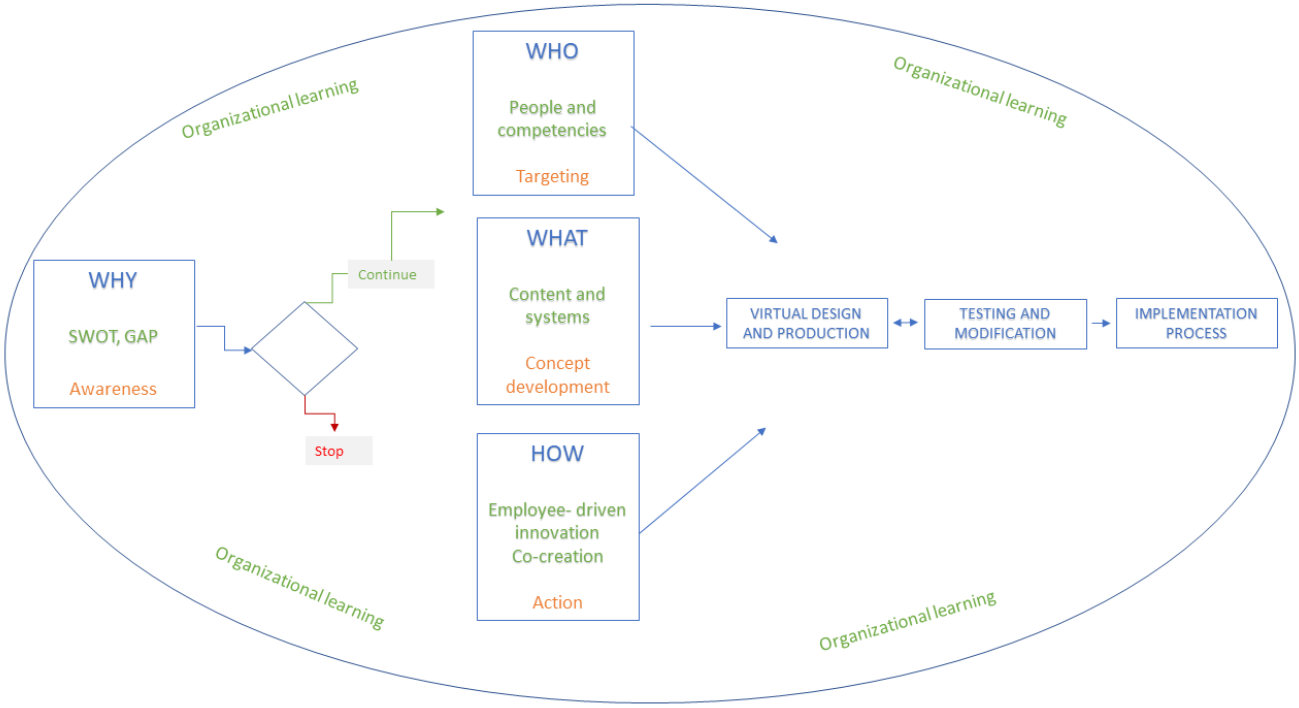


Figure 1 MaXIt: Guidelines for Managing XR Initiatives

The phase why aims to increase awareness, *who* is important for targeting, *what* for concept development and *how* aims to facilitate for effective actions.

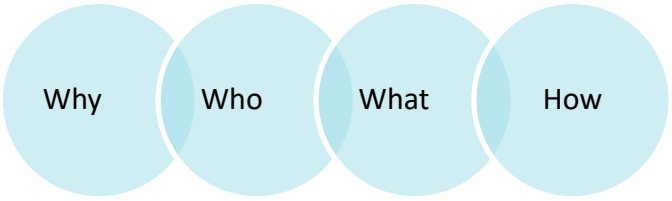
After the four phases, the three processes of designing/producing, testing and modifying and implementation are shown. These processes are not linear because the input for testing and modification will be used as input for virtual design and production.

The process is surrounded by a circle that illustrates and emphasizes the importance of knowledge management to facilitate for organizational learning. Organizational learning is important so you can go from an innovative idea and testing new technology, to using XR as an effective tool to

achieve the objectives. This can be done by facilitating a learning-loop that creates, retains and shares knowledge about the XR- initiatives making the knowledge independent of individuals and allowing the organization to stay competitive in an ever-changing environment.

4.1 The Four Phases

One way to illustrate important considerations to take into account in the process of managing XR initiatives is to enhance four phases that summarizes important focus areas you should have as a manager, entrepreneur and/or project manager; why, who, what and how.



Why?
When you have opened your eyes to the possibilities with XR- technology and you are interested in trying it out in your organisation, always start with the phase "Why". You should use a good amount of time to describe the objectives of the concept you are thinking. Describe the vision rooted in the organisation's strategy. Evaluate needs and reasons for using XR. SWOT analysis or/and GAP analysis might be good tools to work with when it comes to the question of why you should invest in an XR concept. SWOT stands for strengths, weaknesses, opportunities, and threats. While a SWOT analysis can make it easier to plan your future activities, a GAP analysis involves the comparison of actual performance with potential or desired performance compares the actual performance with the potential performance.

Who?
The phase "Who" involves working with evaluating who should be incorporated in the process and an analysis if you have the necessary competencies available or if there is a need for sub-contractors and/or external consultants. Working with digital innovation and with complex digital technology like XR – there is a need for a holistic approach and interdisciplinary teams.

What?
What involves working on two main factors – what will be the content in the XR solution and what XR systems should be chosen. Since XR is an umbrella term that encompasses AR, VR and MR – there are a lot of different systems to choose between. See appendix B for an overview of XR systems (HMDs). Going back to phase one and the objectives – evaluate if there is a need to develop the content or if it is possible to use something that is already produced of others. See appendix C for examples of content platforms and appendix D for examples of content applications. This question also depends on rights and creative common licences of XR content that might be available for free on various content platforms

How?
This phase involves process management and management at a strategic level that will influence the activities in the process. By combining principles of participatory design, iterative design and employee driven innovation you can facilitate for an effective and effectful development process within an organisation.

In general, giving those who are destined to use a product or service a critical role in its design is crucial. Those who ultimately will have to use or be affected by the implementation of technology in a workplace should have a critical role in the design. This is based on Participatory Design (PD) which is a process of reciprocal learning, co-realization and the sharing of decision-making power among relevant stakeholders in the design process. PD practices often incorporate generative techniques, such as co-design to enable participants share their thoughts and ideas by the act of making artefacts[21]. An iterative design process is based on changes being easiest and less expensive to implement in the earliest stages of development. The first step in the iterative design process is to develop a prototype that should be evaluated by a focus group. Information from the focus group should be synthesized and incorporated into the next iteration of the design. The process should be repeated until user issues have been reduced to an acceptable level.

Employee- driven innovation is an umbrella term for the employee's active participation in the development of new solutions. This might involve new products, services, processes, or business models. Involving the employees in innovation processes can provide for benefits like improved work processes, new products, and increased employee satisfaction. The conditions for employee-driven innovation are different in various organisations, but there are some key common cultural features like engagement, trust, autonomy, safety, tolerance, and openness. When it comes to tools for employee driven innovation, the conversation is the most important one. The good conversation characterized with a willingness to convey and to listen. Other tools you can use are social media like yammer to discuss ideas, mind mapping and design thinking[22].

[21] Van Mechelen, 2016.
[22] Nærings- og handelsdepartmentet, 2011.

4.2 15 steps to get you started

Based on a model developed of Pantelidis (2009), recommendations from the XR association (n.y) and further developed with our experience working as project managers and researchers within this field, we have developed a process with 15 steps that you can use to help you get started with planning an XR-initiatives in an organisation.

STEPS	QUESTIONS	OBJECTIVE
1. Find out why.	Why should we use XR? What are the potential benefits of the VR/AR/MR-technology for us?	Focus on solving business problems.
2. Define goals.	What is the objective of the XR solution? For example, cost reduction, technology enhanced learning, reducing errors and/or increased training volume. What are our competitive advantages? Do employees lack specific skills to achieve their goals? Do we have any financial difficulties? Are there any unfulfilled customer needs we can satisfy? Where are we now vs where we want to be? How can we close the gap between where we are and where we want to be? Do you have high risk/high cost environment that could benefit of XR-technology?	Make your goals achievable.
3. Choose the XR- system.	What XR- technology is suitable to for the selected objectives? VR via desktop or HMDs? AR via smartphone, tablets, projectors or HMDs? Are there any OHS issues to consider if it will be used on a shop floor or in production?	Select the appropriate software and hardware.
4. Identify necessary competencies and accessible employees and competencies.	What competencies will be required? Who has competencies about the objective/theme? Who is motivated to work with this? Who has the interpersonal skills required? What is the target group? Do we have the necessary competencies in house or is there a need for external assistance?	Involve your employees.
5. Select co-design group.	Who should be included in the co-design group? Is it a smart move to have representatives from different departments? Should managers be included in the pilot group? Who likes to share	Design a user-centred XR-solution.

	knowledge and experiences with their colleagues?	
6. Introduce the technology and possibilities for XR for the pilot group.	How familiar are the members of the pilot group with the technology? How familiar are the members of the pilot group with the relevant topic? Can you arrange a workshop or other meetings where the pilot group can be introduced to the technology or topic of interest? How can you collect ideas and input from the pilot group in this phase?	Onboarding for the pilot group.
7. Evaluate and document.	What data will be collected and how can this data contribute to organizational learning? What ICT systems do you have to register knowledge and where can employees share their ideas and experiences? How can you facilitate for organizational learning where the evaluations, feedbacks and experiences will be shared with the rest of the organisation?	Measure results and adjust accordingly.
8. Evaluate ideas for content and XR systems.	Is there a need to develop content or is it possible to use already produced XR content? What objectives are suitable for 3D simulations? What real-world environments/situations can be enhanced with computer- generated information? What level of realism is needed? What type of immersion is wanted? What kind of interaction is wanted? What is your budget? Is there a need to make alternatives for those who can't use HMDs because of health issues like epilepsy, use of pacemakers, astigmatism etc?	Content ideation.
9. Design and build virtual environment.	How to design a specific learning experience that best meets the pedagogical needs for the users? How can you design a virtual environment that is both physically and psychologically comfortable? How can you create a good interaction between the users and the simulated environment?	Design a seamless and immersive experience.

	Have you taken into consideration cybersickness, eyestrain and neck and arm ergonomics?	
10. Test the prototype with pilot group.	How many people? Who do you need? How can you test the prototype with the pilot group? How should you collect feedback from the pilot group?	Measure results and adjust accordingly.
11. Modify prototype.	How can you modify according to evaluation of the pilot group? What can be done within budget?	Measure results and adjust accordingly.
12. Test the product with target group.	Who is the target group? How many should test the product? How will you collect the feedback from the target group?	Measure results and adjust accordingly.
13. Modify product.	How can you modify according to evaluation of the pilot group? What can be done within budget?	Measure result and adjust accordingly.
14. Make an internal XR learning strategy.	What should we do with all the data that becomes for accessible with AR and VR? Should we make guidelines for best practices for the employees? Should the pilot group be certified in the technology and have the role as teachers/trainers for their colleagues?	Organizational learning.
15. Implement the XR product.	Where should the XR product will be used first? Are the physical environments /locations suitable for use of the XR solution? Ref, voiceover, biofeedback, embodiment. Will it be used individually or in groups and is there a need for privacy or physical guidance?	Implementation.

5 Summary

This is a manager's guide to XR that is divided into three parts. An introduction to what XR is, what XR can be used for and how to manage XR initiatives in organisations.

Extended Reality (XR) is an umbrella term that encompasses augmented reality (AR), mixed reality (MR), virtual reality (VR), and other forms of alternate, expanded, or immersive reality applications, including those not yet invented. VR is a technology that allows humans to immerse into a reality that is entirely different from a real one or that replicates reality. AR refers to a real-world environment enhanced with computer-generated information. MR is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time.

XR have the potential to transform the way we work, communicate, and experience things. Many sectors are seeing the value of investing in XR capabilities, particularly education, architecture, engineering, construction, manufacturing, and healthcare field. XR is being used for both mental and physical health as well as being used as learning tools for healthcare workers. The manufacturing industry is regarded as one of the most mature in its adoption of XR devices. XR-technologies can assist operators to become smarter operators' in their future factory workplaces.

MaXIt- Managing XR- initatives – is a set of guidelines we have developed based upon our many years of experience with XR projects in organisations. MaXIt gives an overview of important evaluations and reflections a manager should take into considerations when managing XR-initiatives in an organisation. We also present two tools to use when managing these processes: The Four Phases and 15 steps to get you started.

A Terms and definitions

Augmented reality (AR)	Augmented reality (AR) refers to a real-world environment enhanced with computer-generated information such as sound, video or graphics.
Desktop virtual reality	Virtual reality environments that are delivered via a computer monitor and mobile device screen (tablet or smart phone). Interaction in the virtual environment is by using a keyboard, mouse, touch screen, joystick or other gaming device.
Extended realities (XR)	An umbrella that encompasses augmented reality (AR), mixed reality (MR), virtual reality (VR), and other forms of alternate, expanded, or immersive reality applications, including those not yet invented.
Head mounted display (HMD)	A head mounted display (HMD) is a device worn over the eyes that displays virtual objects and environments.
Highly immersive virtual reality	Virtual reality delivered via a head mounted display (HMD) in which the user has a high degree of agency (ability to act) by manipulating virtual objects, interacting with other users and computer-generated non-player characters, and having the ability to create within the virtual environment
Immersive virtual reality	Virtual reality delivered via a head mounted display (HMD) that gives the users the impression that they are in the virtual environment.
Immersion	Where the properties of a technology (visual and auditory stimuli) are designed to allow the user to feel a sense of presence (‘being there’) in a virtual environment.
Immersive learning	Immersive learning is the process of learning with the usage of a simulated or artificial environment.
Mixed reality (MR)	Mixed reality (MR) overlays and anchors virtual objects on to the real world and often allows users to interact with these objects. Sometimes the term is used to refer to the inclusion of physical objects that can be interacted with as part of a virtual environment. The term ‘mixed reality’ is relatively new and still being

	defined.
Smartphone AR	Smartphone AR is where an augmented environment layers virtual content where digital objects and information are layered onto a real-world image captured from a device's camera.
Virtual reality (VR)	A 3D computer-generated world which can be a highly imaginative or realistic simulation.

B XR systems

Head Mounted Display for VR/MR
A head mounted display (HMD) is a device (goggles or a headset) worn over the eyes that displays virtual objects and environments like Google Cardboard, Samsung VR Gear and Oculus Rift. Virtual reality HMDs completely block out the real world replacing it with a virtual world. Mixed reality HMDs allow the user to see the real world and augment or anchor virtual objects in it so that the user can interact with these objects, like smartglasses and the Microsoft HoloLens and Magic Leap. Users may feel uncomfortable wearing a VR headset because of headset weight, headset warmth, or the amount of airflow inside the headset[23] .

Six degrees of freedom platforms (6DOF) like the Oculus Rift, HTC Vive and PlayStation VR support full positional tracking and generally require 360-degree tracking equipment to translate the user's motion into the virtual world in real time. 6DOF devices feature tracking in six orientations and is able to track users' head movements and their position in threedimensional space. Three degrees of freedom platforms (3DOF) like the Oculus Go and Samsung Gear VR use orientation tracking and kinematic models to offer users an immersive experience. 3DOF platforms track users' rotational motions (pitch, yaw, and roll), but not their translational motions (forward/back, up/down, left/right)[24]. Oculus Rift and HTC Vive are the market leading VR- headsets with 45 % and 41 % of the users[25]. Samsung Gear VR har been one a popular HMD in organisations where you connect the HMD to your Samsung smartphone and use the benefits of it being wearable and wire-free, but now the portable and wire-free Oculus Quest is very popular. Oculus Quest has the same advantages of being a wearables device and lower costs than the stationary solutions like HTC Vive and Oculus Rift. You can also choose between 64GB and 128 GB model with a price gap between the two. The Rift S is still technically Oculus's PC headset, but in November 2019 a new update will make it so connecting a USB-C cable from your Quest to your PC will allow you to run Rift titles on Quest.

Head Mounted Display for AR/MR
Magic Leap One lets in natural light waves together with softly layered synthetic light fields. The sensor suite makes digital objects contextually aware. Spatial Audio blends virtual objects with the real world by relaying distance and intensity and it can be equipped with a lens insert based on your personalized prescription for eyeglasses. The device does not require connection to the PC and base stations, and the processor unit can be carried in your pocket or belt. A user does not need a powerful PC or a large room for the game. Everything is already in the kit. It is one of the lightest and ergonomic AR and VR devices.

Hololens 2 from Microsoft use cloud and AI services from Microsoft. It has a dial-in fit system designed for extended use so you can keep your glasses on because the headset slides right over them. The HoloLens 2 headset is a self-contained computer with Wi-Fi connectivity with no wires or external packs.

[23] XR Association (.n.y).
[24] XR Association (.n.y).
[25] Hadwick, 2019 - 2020

Overview of VR/MR HMDs

System	Samsung Odyssy +	Samsung Gear VR	HP Reverb Pro	Oculus Rift S	Oculus Quest	HTC Vive	HTC Vive Pro	Primax 5K Plus	Valve Index
Reality	VR/MR	VR/MR	VR/MR	VR/MR	VR/MR	VR/MR	VR/MR	VR/MR	VR/MR
Year	2018	2017	2019	2019	2019	2016	2018	2019	209
Weight	645 g	345 g	498 g						
Panel	Amoled	-	LCD	LCD	OLED	OLED	AMOLED	LCD	LCD
Visuals	90hz 110” FOV Adjustable IPD 1440px 1600p	101˚ Fov, Fixed IPD62 mm	90hz 114” FOV Fixed IPD 2160px 2160p	80hz 95” FOV Fixed IPD 1280px 1440p	72hz 95” FOV Adjustable IPD 1440px 1600p	90hz 110” FOV Adjustable IPD 1080px 1200p	90hz 110” FOV Adjustable IPD 1440px1600p	90hz 200” FOV Adjustable IPD 2560px1440p	144hz 110” FOV Adjustable IPD 1440px1600p
Connectors	1x USB 3.0 HDMI 1.4		1x USB 3.0 Display Port 1.2	1x USB 3.0 DisplayPort 1.2	1x USB-C 3.0 (Charging)	1x USB-C 3.0 HDMI 1.4	1x USB-C 3.0 DisplayPort 1.4	1x USB 3.0 DisplayPort 1.4	1X vIRTUALlINK/ 1x USB3.0 DisplayPort 1.4
Tracking	Inside-Out (Two camera)		Inside-Out (Two camera)	Inside-Out (Five camera)	Inside-Out (Four camera)	Base station	Base station	Base station	Base station
Store	Windows Store Steam	Oculus Store	Windows Store Steam	Oculus Store Steam	Quest Store	Vive Store Steam	Vive Store Steam	Steam	**Steam**
Price	USD 499 EU 442		USD 649 EU 598	USD 399 EU 449	USD 399/499 EU 449/549	USD 499 EU 599	USD 1098 EU 1199	USD 699	USD 999 EU 1079

Overview of AR/MR HMDs

System	Hololens 2
Price	$3500 USD, $125 USD per month Enterprise, $99 USD per month Developer
Display	Optics: See-through holographic lenses (waveguides) Resolution; 2k 3:2 light engines Holographic density: >2.5k radiants (light points per radian) Eye-based rendering: Display optimization for 3D eye position
Sensors	Head tracking: 4 visible light cameras Eye tracking: 2 IR cameras Depth: 1-MP Time-of-Flight depth sensor IMU: Accelerometer, gyroscope, magnetometer Camera: 8-MP stills, 1080p30 video
Audio and speech	Microphone array: 5 channels Speakers: Built-in spatial sound
Human understanding	Hand tracking: Two-handed fully articulated model, direct manipulation Eye tracking: Real-time tracking Voice: Command and control on-device; natural language with internet connectivity
Environment understanding	6DoF tracking: World-scale positional tracking Spatial Mapping: Real-time environment mesh Mixed Reality Capture: Mixed hologram and physical environment photos and videos
Compute and connectivity	SOC: Qualcomm Snapdragon 850 Compute Platform HPU: Second-generation custom-built holographic processing unit, Memory: 4-GB LPDDR4x system DRAM Storage: 64-GB UFS 2.1 WiFi: 802.11ac 2x2 Bluetooth:5.0 USB: USB Type-C
Fit	Weight: 566 g Single size Fits over glasses
Software	Windows Holographic Operating System, Microsoft Edge, Dynamics 365 Remote Assist, Dynamics 365 Layout,

	Dynamics 365 Guides, 3D Viewer, OneDrive for Business

System	Magic Leap One
Price	Personal Bundle: 2 295 USD Developer Bundle: 2 70 USD Developer Bundle: 3 290 USD
Display	AR- see through, VRD Field of view horixzontal 50˚
Environment understanding	6DoF tracking (position and orientation)
Compute and connectivity	CPU: NVIDIA® Parker SOC; 2 Denver 2.0 64-bit cores + 4 ARM Cortex A57 64-bit cores (2 A57's and 1 Denver accessible to applications) Memory: Internal capacity 128 GB- Actual available storage capacity is 95 GB. RAM: 8 Gb Wifi: 802.11ac/bg/n Bluetooth:4.2 USB:USB Type-C

C Development platforms

Platform	Description
Unity	Mobile Development engine. A cross-platform tool launched by Unity Technologies. One of the most used development platforms with tutorials and guides. One of the most famous game creation software among developers.
Unreal Engine	A platform that allows changes and modifications with no need of programming or changing codes.
CryEngine	CryEngine is a powerful game development platform. Full source code available. All features. No licensing fees.
Simmetri	Simmetri is a creative VR workbench, mixed reality playground and interactive design studio
Amazon Sumerian	Amazon Sumerian lets you create and run VR, AR, and 3D applications quickly and easily without requiring any specialized programming or 3D graphics expertise.
Google Daydream	Daydream makes developing high quality mobile VR easier, efficient and more accessible.
Blender	Blender is the free and open source 3D creation suite. It supports the entirety of the 3D pipeline—modelling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation.
Google Blocks	With Blocks, you can create models in VR. With six tools you can create models as simple as a mug and as complex as a spaceship.
Wings3d	Wings 3D is an advanced subdivision modeler that is both powerful and easy to use. Wings 3D offers a wide range of modelling tools, a customizable interface, support for lights and materials, and a built-in AutoUV mapping facility.

D Content applications

There are several content applications for XR content you can purchase or even get for free, for XR platforms like Google, Oculus, PlayStation, YouTube and so on. Below is a short overview of some applications that are free.

App	Description	Supported platforms
Within	Offers users a single platform through which they can discover great VR content from creators around the world for free. The app features immersive VR videos spanning across a variety of genres, from fictional tales to serious documentaries	Android (Google Daydream), iOS, Windows, Oculus, PlayStation VR and HTC Vive
BBC EartLh, Life in VR	A Google Play Award winning app that allows users to experience the natural world in VR	The app is supported by Google Daydream exclusive.
InCell VR	Avirtual reality app for educational purposes. InCell VR has been designed to teach you how the human body works by taking you down to the cellular level and helping you understand just what goes on inside the building blocks of our body.	Google Cardboard/Daydream, iOS, Samsung Gear VR, Windows, HTC Vive, Oculus
Dream Vision VR	Dream Vision VR aims to enhance your augmented and virtual reality universe with a collection of the best VR apps, videos, and image content available.	Android and iOS
Fulldive VR	A sort of social media app for virtual reality which hosts 100 percent user generated content that you can watch on your VR headset. Being a social platform, the app allows you to add friends from around the world and experience their content. You can even share VR content that you created on the platform.	Android (Google Daydream/Google Cardboard), iOS

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