XR technologies for industrial SMEs:

The VAMR*s University-Business Cooperation Handbook

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Table of content

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List of figures

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List of abbreviations and definitions

AR	Augmented Reality: a technology that adds digital content into the user's view of the real environment, via various devices such as smartphones, tablets, and head-mounted displays.
HEI	Higher Education Institute.
MR	Mixed Reality, a technology that merges real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. Often viewed as a more advanced version of AR, where the digital content interacts with the real environment more extensively.
ROI	Return on Investment.
SME	Small and Medium-sized Enterprise.
SOTA	State of the Art
VAM*Rs	Virtual, Augmented and Mixed Realities (project)
VR	Virtual Reality, a technology for creating an immersive and interactive three-dimensional computer-generated environment, in which the virtual objects have spatial presence. Head-mounted displays are often used in creating the VR experiences.
XR	Extended Reality, an umbrella term for AR, MR and VR.

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Introduction to the VAMR*s University-Business Cooperation Handbook

Chapter 01

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1. Introduction to the VAMR*s University-Business Cooperation Handbook

Authors: José Laan and Sandra Verweij, Parbleu (The Netherlands)

Preamble

Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) commonly referred to as Extended Realities (XR)- are expected to have a major effect on organizations in the coming decades, with no exception to the manufacturing industry. Several forecasters predict that AR and VR markets will grow significantly in the coming years. Besides the rapid technical developments with XR technologies, significant external factors, namely the COVID-19 pandemic, have spurred further interest into using XR in organizations. Despite the hype around XR, many manufacturing SMEs are still not sufficiently aware of the potential of these technologies, how they could be used to support their business processes, or what challenges they might face when adopting them, as reflected in the VAM Realities European Survey. Companies need to be aware of these technologies, where and how they can be used, and what factors can promote the added value, return on investment and effective adoption into their organizations. In order to address this topic, the Erasmus+ co-funded VAM Realities (VAM*Rs) project was launched at the beginning of 2020 to help European manufacturing SMEs to better understand the impact and opportunities of these technologies and to make informed decisions on where and how to adopt and integrate them in their business operations.

The VAM Realities (VAM*Rs) project

With the speed of technical developments and the mass of information, products and services available, it is difficult to keep track of things. How can manufacturing SMEs find out quickly and reliably which XR solutions are the most useful and target-oriented for their needs? And how can Higher Education Institutes (HEIs) support them in their search and implementation processes?

To address these questions, the following products and results are developed in the VAM Realities project:

European survey with SMEs

300 SMEs have been questioned to find out how much they know about the potential of VR/AR/MR and how they are already benefitting from these technologies. The results of this survey were used as a reference framework for the Gap Detectors (see below), the Coaching Program and the VAMR*s University-Business Cooperation Handbook (in short: Handbook) that is now in front of you. Link: VAM Realities European Survey

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VR/AR/MR Technology Report

This *State-of-the-Art Report (SOTA)* provides an overview of the most important and efficient XR technologies currently available to companies and indicates what kind of hardware and software is successfully used in the various industries, and the investments required. The report also includes a series of uses cases to illustrate the adoption potential of the technology. The State-of-the-Art report is revised on an ongoing basis to reflect developments in the market. Link: VAM Realities State of the Art report

SME Skills Gap Detector

The *Skills Gap Detector* is a convenient and uncomplicated online self-assessment tool that allows companies/SMEs to find out how well prepared they are - or not - for the increasing importance of XR in their industries.

Training Gap Detector

The online *Training Gap Detector* allows higher education institutions to find out how well (or not) they have already incorporated XR into their curricula in order to best prepare students for these developments in the professional world.

VAMR*s XR SME Coaching Program

The *XR SME Coaching Program* offers one-to-one and independent support to SMEs in the adoption of XR technologies, regardless the pre-existing level of knowledge and experience in this technology. The coaching program allows SMEs an introduction and hands-on experience of this technology, right through to the development of XR content and integration into their business operations.

VAM Realities Challenge

A European competition for students, start-ups and other companies to develop innovative XR solutions for manufacturing SMEs' needs that were identified during the project. The call for tenders was launched in October 2020 and the prize giving ceremony was held in May 2021. The winning XR applications are integrated into the XR SME Coaching Program for SMEs to experience. Link: VAM Realities Challenge results

European Network

The online *VAM Realities Network* consists of over 250 members now, stemming from industry, academia and research mapped across Europe, who have a shared interest in XR development and the activities of the VAM*Rs project. The network is a significant resource for organizations who wish to collaborate and connect with like-minded partners, locally and internationally. Link: VAM Realities European Network

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Expert Panel

The online *VAMR*s Expert Panel* has more than 100 contacts now in all EU countries, who can help SMEs and supporting HEIs with XR issues or advise on the selection and use of this technology. The Expert Panel is mapped to locate experts and their portfolios in each region and country across Europe. Link: VAM Realities Expert Panel

Community of EU projects

This is a community of over 35 EU projects in the field of VR/AR/MR. It provides an insight into the diverse applications of this technology in society and business and offers projects a platform for presentation, exchange and mutual learning. Link: VAM Realities Community of EU projects.

The above VAMR*s products and tools are described in more detail in chapter 9 and 10 of this Handbook.

Objectives of the Handbook

This **VAMR*s University-Business Cooperation Handbook** is another main product of the VAM Realities project. It aims to address how Higher Education Institutes can support manufacturing SMEs to adopt and integrate XR technologies successfully into their business operations. Therefore, the Handbook is aimed primarily at program/curricula developers of HEIs, although chapters 2 - 9 can also be consulted directly by management and staff of manufacturing SMEs.

Readers of this Handbook

HEIs: If you are working in a Higher Education Institute in one of the roles listed below, and are involved in or plan to be involved to collaborate with industry and manufacturing SMEs on XR topics, then you are the primary target of this Handbook. Roles can include: lecturers, professors, academic staff, researchers, project coordinators, industry engagement and/or enterprise liaison managers.

SMEs: If you are working in an SME in the manufacturing sector and are interested in increasing production efficiently, optimizing work processes and in learning how new technology can support your business, then you, and your organizations' management and staff will benefit from this Handbook.

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Other: If you are generally interested in the developments going on in XR technology and how it will shape industry in the coming years, then this Handbook is a significant resource to illustrate and explain these developments. It can be used to support the adoption of this technology in business and industry.

The VAMR*s University-Business Cooperation model

This Handbook provides a *VAMR*s University-Business Cooperation and Coaching Model*, as a hands-on tool and in-depth assistance for HEIs who are supporting SMEs with the introduction and integration of AR/VR/MR technology into their business operations. The graphic below is a visualization of this model. It is a suggested approach to the learning process and a '**route map**' to adoption and implementation, with entries and exit points at each learning level. It displays the potential finishing outcomes for HEIs and for SMEs in the cooperation process, and the comprehensive skills that can be acquired at each level. The route map is a simplification of an iterative process, to illustrate the progress learning steps and potential outcomes of the cooperation, in which the paths to achievements can be easily identified. The route map suggests how to utilize fully the accompanying VAM*Rs University Business Cooperation Handbook and other VAM*Rs Tools, and at what point to introduce them. The model is explained in depth in chapter 10 of this Handbook.

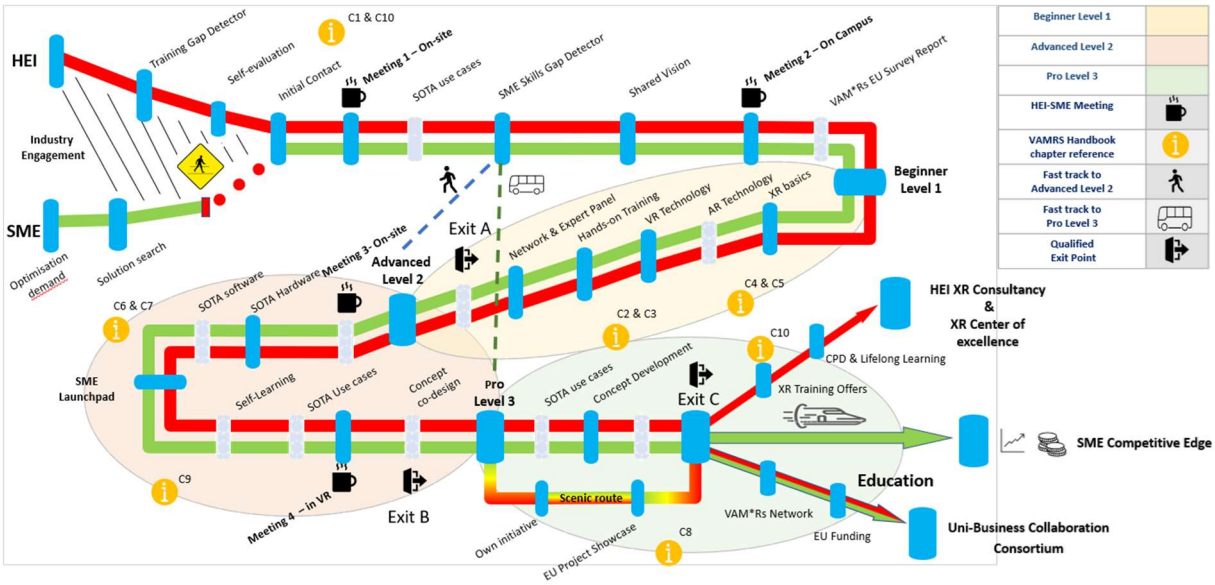

*Figure 1: The VAM*Rs HEi - SME Cooperation route map*

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Structure of the Handbook

Chapters 2 - 7 of the Handbook focus on possible fields of XR application in manufacturing SMEs, while taking the typical business processes of these companies as a starting point. For each business process, specific XR opportunities are being described, as well as challenges, suitable tools and solutions, illustrated with relevant use cases.

Chapters 8 - 9 deal with legal, managerial and organizational challenges related to implementation of XR technology.

Chapter 10 elaborates on HEIs' ability, methods and tools to support manufacturing SMEs in adopting and implementing XR technology in their businesses and clarifies the use of the *VAM*Rs Cooperation and Coaching Model* during the VAMR*s Coaching Program and thereafter.

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Developing Augmented Products in manufacturing SMEs

Chapter 02

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2. Developing Augmented Products in manufacturing SMEs

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Introduction

One of the defining aspects of the beginning of the 21st century is the mass introduction of smartphones. From clunky portable phones and pagers to cellphones, we have arrived at the point when virtually anyone today owns a smartphone – a fully functional and rather performant pocket computer with

- a fairly large screen which is capable of displaying lots of information including complex three-dimensional geometry,
- a very capable camera rivaling the performance and output quality of semi-professional photo cameras,
- an almost constant Internet connection and information about its geolocation.

But what truly paved the way for the popularity of smartphones, was, in many respects, the simplicity and power of the touch gesture first demoed in 2006 and quickly picked up by consumer electronics manufacturers[1] [1]. Whereas using a computer requires skills that, given the history of humanity, are rather unnatural (like controlling the on-screen cursor location with a computer mouse), the touch gesture makes using a device equipped with a large touchscreen so easy that users can quickly learn to operate it. Furthermore, voice commands for smartphones, initially quite limited in what can be achieved with them, have also evolved significantly, partly due to co-evolution of online cloud services. In the scope of the consumer market, Apple Siri, Microsoft Cortana, Amazon Alexa, and Google Assistant are now practically household names.

At the same time as the smartphone was gaining massive adoption, a few developers were working on what would later be known as Oculus Rift first released in 2012 ¬– a virtual reality device which would allow to transport a user into an artificial world through the effect of

[1] J. Jerald, The VR Book: Human Centered Design for Virtual Reality, Association for Computing Machinery and Morgan & Claypool Publishers, 2016.

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complete immersion[2] [2]. Both virtual reality and its close relative augmented reality (the latter is the cornerstone of this chapter) fall into the family of extended reality technologies (XR). However, the benefit of AR is that the user is never fully immersed in an artificial environment, rather experiencing the augmentation of the actual surrounding environment.

During the same time, another area of research and development has experienced some dramatic developments - namely, artificial intelligence. In its many incarnations, it nowadays serves as the backbone of a countless number of services from market predictions to traffic navigation to computer vision, the latter presenting more interest due to the direct applications to augmented product design.

Finally, with widespread adoption of Internet access and the simplicity of connecting almost any device to the Internet, the Internet of Things concept emerged ¬– meaning that we have many interconnected “things” in the cloud which we can use to collect and communicate data, apply as controllers for various actuators (e.g., to achieve climate control in a heating, ventilation, and air conditioning case) and so forth. Together, this now forms an intelligent computational cloud infrastructure.

Now, when one combines all of the above together one finally gets fully fledged augmented products. In this chapter, augmented products are explored in some detail and the benefits of this business area, opportunities, potential for return on investment, helpful tools, use cases and examples are discussed. We specifically target manufacturing SMEs, but some of the content also serves as a general introduction to the topic.

Motivation and Opportunities

Augmented products, where actual hardware devices are concerned, are typically broken down into:

1. Mobile based AR (smartphones and tablets ¬– handheld, using the camera).
2. Standalone device-based AR (headsets that predominantly use a camera to understand the surrounding environment, though not all of them do).

Given the widespread adoption of mobile devices, it is not difficult to see that if AR is applied well, the benefit to the end user, whether consumer or industrial markets are

[2] D. Saffer, Designing Gestural Interfaces: Touchscreens and Interactive Devices, O'Reilly Media, 2008.

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concerned, is remarkable[3] [3]. To appreciate this, the user with a modern smartphone need not do more than use Google Search and typing, say, “husky” into the search field. One of the links returned is a 3D model of the Siberian husky dog which can be placed into the user’s environment in one more click (see contemporary investors, market analysts, and AR/VR/MR system integrators, as well as enterprise users, expect to see a real return on investment (ROI) for these unique technologies in the next five years, as underlined by the Gartner Hype Cycles for Emerging Technologies.”).

This example shows that the potential for AR technology has already been successfully realized in some consumer applications. But apart from the “wow effect” what are the actual advantages? To answer this question, one must look towards specific industrial fields. The following discussion is presented in the context of return on investment. Directly quoting Kress[4] [4]:

“Unlike in the previous AR/VR boom of the late 1990s, contemporary investors, market analysts, and AR/VR/MR system integrators, as well as enterprise users, expect to see a real return on investment (ROI) for these unique technologies in the next five years, as underlined by the Gartner Hype Cycles for Emerging Technologies.”

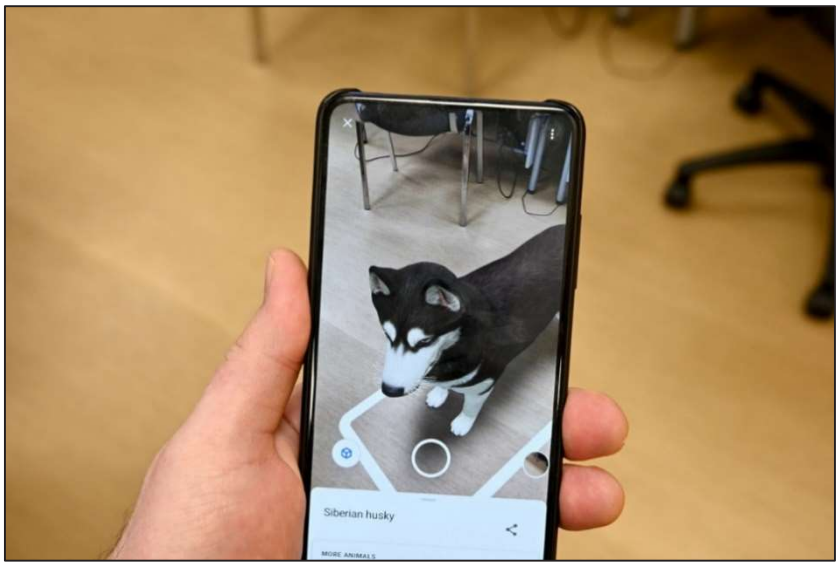

Figure 2: Animated artificial Siberian husky dog rendered in the user’s actual environment using a smartphone and Google Search. The user environment is scanned and mapped to the digital environment using an intelligent method.

(Photo credit: original photo by the author)

[3] Rauschnabel, P. A., "Augmented reality is eating the real-world! The substitution of physical products by holograms," *International Journal of Information Management,* vol. 57, p. 102279, 2021.

[4] Kress, B. C., Optical Architectures for Augmented-, Virtual-, and Mixed-Reality Headsets, SPIE, 2020.

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Figure 3: A futuristic car dashboard concept. Augmented reality is used to enhance driving safety and ease of navigation.

Source: https://blog.aisinsurance.com/2019/02/05/car-safety-features-future/

Furthermore, Kress goes on to outline the sustainability aspect of "MR for enterprise". The ROI there is said to be "mainly cost avoidance" and related to the following applications:

- Faster learning curves in training for new employees, higher productivity, and efficiency.
- Lowering of downtime, waste, and operational costs.
- Collaborative design, remote guidance, better servicing, and monitoring.
- Higher QA in manufacturing.
- Enhanced product display, demos, and better user experiences.

Specific sectors that are said to have shown a tangible MR ROI are concentrated in

- Manufacturing ¬– automotive, avionics, heavy industrial products.
- Power, energy, mining, and utilities.
- Media and telecommunications.
- Healthcare and surgery.
- Financial services.
- Retail, hospitality, and leisure fields.

Getting Started with Augmented Products

So far, the context and motivation for looking into augmented products for business purposes has been discussed. However, to really get started, one must also learn the basic concepts upon which the design and development of augmented products is largely based. Without

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this knowledge, it is not possible to coherently address the challenges that present themselves in the rapidly growing field of augmented products. So, this section begins with introducing some key concepts and brief explanations.

First, looking at the industrial and manufacturing landscape, one today finds it in a transitional state towards so the called *Industry 4.0*. The name hints at the fact that we are experiencing the "fourth industrial revolution". In a nutshell, Industry 4.0 follows the continued trend of digitalization of products and services on a global scale including both industrial and consumer markets.

Then, as a vital component of Industry 4.0, one has *cyber-physical systems*. While the name may sound somewhat intimidating, the idea simply points to the relationship between the human and modern technology. To quote the NIST definition[5] [5]:

Cyber-Physical Systems (CPS) comprise interacting digital, analog, physical, and human components engineered for function through integrated physics and logic. These systems will provide the foundation of our critical infrastructure, form the basis of emerging and future smart services, and improve our quality of life in many areas. Cyber-physical systems will bring advances in personalized health care, emergency response, traffic flow management.

Finally, because cyber-physical system technology intrinsically relies on a digital representation of data, one has the fundamental concept underpinning augmented products, which is the digital twin. The idea of DT in itself is simple but is also subject to different interpretations. For example, the NASA (2012) definition of a digital twin is as follows[6] [6]:

DT is a Multiphysics, multiscale, probabilistic, ultra-fidelity simulation that reflects, in a timely manner, the state of a corresponding twin based on the historical data, real-time sensor data, and physical model.

Tao et al. in their seminal article [6] propose a more complete structure of a digital twin which is reproduced here as a simplified diagram in Figure 4.

It makes sense to focus on the components of the virtual entity ¬– the *digital twin*. Typically, it has the following components:

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5 National Institute of Standards and Technology, *Cyber-Physical Systems,* 2021.

6 F. Tao, H. Zhang, A. Liu and A. Y. C. Nee, "Digital Twin in Industry: State-of-the-Art," *IEEE Transactions on Industrial Informatics,* vol. 15, p. 2405–2415, 4 2019.

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- A three-dimensional digital model of the physical entity. This is used for visualization purposes, such as showing the actual construction of the physical entity or reporting on the real time telemetry data coming from a certain industrial process.
- Animation showing the operation of the digital twin. For instance, once can think about an application of showing the flow of air in a room in which case a digital twin of the room must be available; another example is an animation of a working petrol internal combustion engine.
- Digital twin construction logic. A model of the inner workings of the digital twin, for example, if a digital twin of a drivetrain is considered, the elements must interact, visually, in the same way they do in the physical entity.
- Digital twin simulation model. A computer program that computes the actual operation of the digital twin that must match the physical entity as closely as possible, especially, if training applications depend on the quality of the model.
- User interface and digital twin interaction logic. Since most digital twins are created with user interaction in mind, this is a highly important aspect of the overall application logic. In many cases, this aspect comes part of a bigger software platform which also provides the user access to 3D models and simulation data.

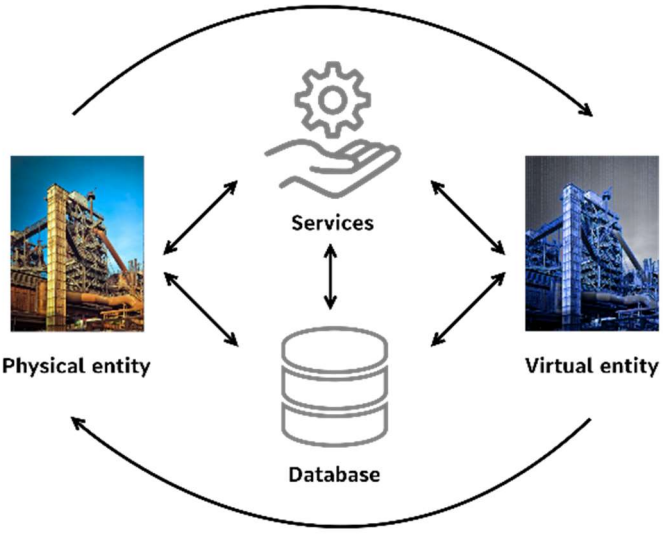

Figure 4: The five-dimensional model of digital twins reproduced in a simplified form from [6]. The dimensions are as follows: (1) the physical entity shown in the diagram as an industrial plant on the left; (2) the virtual entity –– a digital representation of the plant; (3) a database for storing information about both the real plant and its digital twin; (4) services which expose the functions of both the physical and the virtual entity to end users; and (5) all the connections between these nodes.

Source for parts of the diagram: https://viridis.energy/en/blog/role-digital-twins-energy-and-utilities-management

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The five-dimensional model of the digital twin presented here, with respect to augmented products, should not be underestimated. Almost all the elements of Figure 4, including the connections between the nodes, offer business opportunities. Here are a few examples:

- Interconnections between the physical entity and virtual entity: design efficient real time communication between the AR implementation (digital twin) and the real object.
- Database: now, the volume of data coming from the Internet of Things is considerable, one excellent and rather challenging opportunity is to create a graphical user interface for visualizing this data with the possibility for real time navigation of the data.
- Services: there is a chapter that specifically deals with the topic of augmented services, so please refer to it.

With regard to the physical/virtual entity example presented in the figure, the involvement of augmented products in a possible implementation of the digital twin can be outlined as follows.

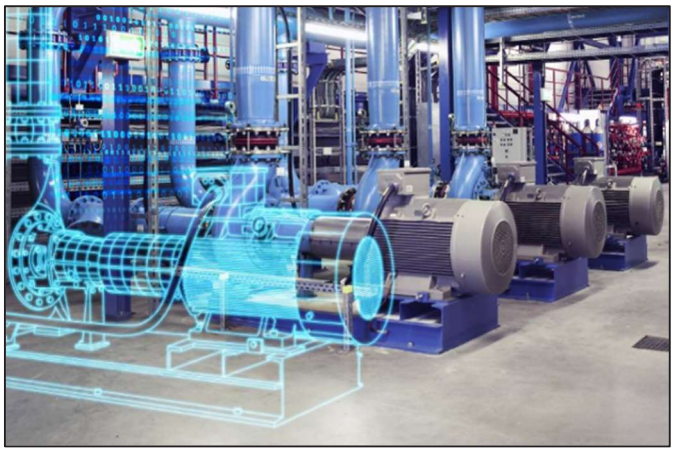

Figure 5: An example of a digital twin of plant machinery. The user can interact with the digital twin to learn the operation without using actual machinery. Thus, there is no down-time for actual working processes, while the user successfully learns to operate the unit.

Source: https://norlean.com/en/blog/digital-twin-a-key-piece-in-industry-4-0/

Depicted in the figure is an industrial plant. There are quite a few items that could benefit from the application of augmented products. For example, one has the following possibilities:

- Create training applications that show the plant workers how to operate the machinery. The instructions are presented in augmented reality over digital twin representations of the actual systems. This situation is depicted in Figure 5. This requires creating corresponding digital 3D models of the plant machinery, designing

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graphical user interfaces and digital twin interaction, and machine operation logic and/or a simulation model thereof towards a smartphone/tablet or head-mounted display application. Specific requirements obviously depend on the desired end result, requirements for envisioned attained skills, and complexity of the machine under study.

- Creating an advanced telemetry application which can be used to monitor running processes. An example of this using a tablet is presented in Figure 6. As telemetry is concerned, the requirements for this application apart from the usual 3D modeling and user interface design include the study and implementation of a real-time computer network which must also support wireless connection to the device the user is using (smartphone, tablet, or, e.g., Microsoft HoloLens 2). Furthermore, accurate environment tracking is needed, since the device must understand which device the user is looking at, for example, the video stream that is coming from the device's integrated camera can be processed.

The take-home message of this section is that you should carefully consider the possibilities stemming from the digital twin concept as depicted in Figure 4. Based on further real-life examples you will be able to come up with ideas about augmented products and their potential for driving a strong business model. In the next chapter, helpful tools for you to get started with augmented products are discussed.

Figure 6: Example of a factory floor scanning application in the form of augmented reality: the additional arrows and warning dialog window appear overlaid on top of the actual system of pipes, valves, and actuators. The user can thus make a quick decision to ensure the continued safe operation of the plant.

Source: https://www.fuzzylogicstudio.io/post/remote-augmented-reality

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Helpful Tools and Solutions

Below, a table providing information about the relation of different AR implementations with use cases is provided. Use this table to decide how augmented products can benefit your business model assuming you want to use AP internally in your company.

Table 1. Augmented products per implementation category with relations to use cases

	Mobile based devices	Wearable, untethered devices	Wearable, tethered devices
Examples	Modern Android mobile phones and tablets, Apple iPhones and iPads.	Microsoft HoloLens 2, Vuzix M4000 Magic Leap.	Varjo XR-1 development kit, Varjo XR-3
Technical aspects	Work well for simple applications where either the user can use a free hand to orient the device as needed for the intended application, or the device can otherwise be fixed using, e.g., a flexible table holder. The devices in question should support ARCore (Android, 7+, Google Certified) or ARKit technologies (Apple, device having an A9 chip or better).	Universal solutions for a wide variety of industrial applications with the best possibilities for users to interact with objects in AR. While being untethered has significant advantages, battery run time has to be considered (on average, this amounts to 3 hours of continued use). Also, the field of view on the current generation (2021) of devices is fairly limited.	At the moment (2021), there are not many such devices on the market capable of combining AR with VR. However, with Varjo XR-3, the user gets the absolute best of both worlds (AR and VR), with the only downside that the device additionally requires a connection to a very powerful desktop computer. They provide the best field of view and graphical fidelity.
Implementation cost	From the hardware perspective, the devices themselves are relatively inexpensive, though it must be checked that the device actually supports the technologies necessary to implement AR (see above). The software development aspect can be rather costly, while there exist software platforms such as Unity and Unreal Engine 4 that can be used for free following certain conditions in the respective license agreements.	The devices provided in the examples are strictly business-oriented, therefore the price tags can be quite high (average price as of 2021 for any listed device is about 2200 EUR). Software development rather costly. Software development platform availability is similar to the mobile development category.	The fact that such devices serve a unique purpose and are strictly business oriented, they are the most expensive. For example, Varjo XR-3 comes with a price tag of 5450 EUR (2021) and requires a subscription to use the device (about 1300 EUR per user per year). Furthermore, a powerful desktop computer is also necessary for each device which can cost around 3000 EUR. Software development costs are similar to the other categories. Software development platform availability is similar to other categories.

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	Mobile based devices	Wearable, untethered devices	Wearable, tethered devices
Set up difficulty	In general, rather simple to set up as the devices and interactions are well known by most users. Depending on which software is used, signing in to a specific service may be required per user.	Setting up may be more difficult, some expert assistance may be needed. Depending on the device, signing in to a specific service may be required per user.	Set up requires expert knowledge in most cases as it additionally involves setting up a reliable tracking system, greenscreen, etc. depending on the application. Varjo XR-3 requires a subscription per user, so the user must log in to use the device.
Use cases	✓ If tablets are used, it is mostly seated applications, as it is not comfortable to walk around holding a big device in front of you. On the other hand, the bigger screen is an advantage when placing objects into the real environment. ✓ Place objects and/or subjects into the real environment and interact with them with screen-based gestures or voice. ✓ Overlay real objects with helpful instructions (assistance for an operator or technician). ✓ Perform quality checks.	✓ The user is free to move in the designated area (e.g., factory floor). Hands remain free at all times. ✓ Place objects and/or subjects into the real environment and interact with them with voice or natural hand gestures. Excellent for training. ✓ Observe the operation of either real objects or their digital twins in real time. Interact with those objects using natural hand gestures. ✓ Overlay real objects with helpful instructions (assistance for an operator or technician), observe real time telemetry or production data. ✓ Perform quality checks and maintenance tasks.	✓ Mostly seated applications. ✓ Works especially well for true-to-life simulation applications (e.g., flight simulators). ✓ Use for applications that require extreme graphical fidelity and the widest field of view.

Next, some plain business models along with their advantages, drawbacks, and risks, are discussed. In Table 2, you will find a summary of some basic business models related to augmented products, with advantages and risks and drawbacks outlined. Note that the table by no means provides complete information about the business potential of AP, but rather gives the foundation upon which further ideas can be developed.

Table 2. Basic business models for augmented products (AP)

Business model	Description	Advantages, Drawbacks, and Risks
Distribution of AP hardware and software	Since XR technology and augmented products are not yet deployed at a large scale, there is still a possibility to establish a business distributing both hardware and software products.	✓ Due to the rapid development of XR technology, there is high demand for it, but not all countries are targeted due to lower supply. Establishing supply chains is essential for many countries to receive cutting-edge hardware. ✗ "Seasonal business" possible depending on which hardware is released.
Hardware development	This business venture requires highly skilled personnel to be employed along with an R&D department. So, rather than pure AR hardware development,	✓ Many opportunities due to missing features for augmented reality (such as, e.g., coherent tactile feedback).

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Business model	Description	Advantages, Drawbacks, and Risks
	developing AR device accessories could be considered.	✗ Hard to compete with large corporations such as Microsoft, Apple, or Facebook, who have serious manpower attached to AR projects.
Software development	Many opportunities, qualified software developers required, excellent potential on return on investment.	✓ Huge potential for return on investment. ✓ Major software platforms for content development like Unity and Unreal Engine 4 can be used for free under certain licensing conditions. ✓ Excellent opportunities in little-explored areas, such as user interface design for augmented products. ✗ High competition in large scale XR software platform space.
3D modeling	Development of the actual content for augmented products.	✓ Open-Source software available (e.g., Blender) that offers a full 3D model development pipeline. ✗ Highly competitive area of development, especially in simple static content creation.
Advertisement in AR	As XR is nearing widescale adoption, this will likely become a huge business.	✓ Opportunities to provide unique solutions for AR advertisement. ✗ Area already heavily influenced by huge corporations like Facebook and Google.
Consultancy services	With solid knowledge on augmented products, one can venture into the consulting space.	✓ International cooperation possible. ✗ Very good understanding of XR hardware and software is required.

Finally, specific helpful tools produced by VAM Realities through the web platform https://vam-realities.eu/ are reviewed. For an opportunity to quickly start with augmented products, go through the following checklist in order. Afterwards, you will have a much better understanding of the subject matter and will be able to move on to working with augmented products.

1. **Survey report on the state of XR in European SME manufacturing companies in 2020**. This document provides insight into the current state of XR awareness and potential for application among European SMEs. Two main components served as the foundation for the report: a general questionnaire and specific interviews conducted with representatives of SMEs. In this document, you will learn which main augmented products are either being used already now, or which are expected to gain adoption in the companies of the interviewees.
2. **State of the Art of XR technologies**. This document serves as a gentle introduction to the topic of XR, the main ideas, concepts, and can be viewed as an extension of the many ideas presented in this handbook. It is an essential read for obtaining a better understanding of augmented products also because of the content part which describes the hardware devices, software applications and platforms, and also use cases, some of which are also highlighted in the following section.

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3. **SME Skills Gap Detector**. An online application that is intended for helping SME representatives to determine what they need to successfully orient their business model towards XR technology adoption. The necessary skills required for developing augmented products were briefly touched upon in this chapter. The Skills Gap Detector is supposed to provide specific feedback concerning this matter.
4. **The Expert Network**. Finally, if you want to learn more about using or developing augmented products, please turn to VAM Realities Experts Network which you can access on the official website (no registration is required). You can find there an expert in your area and contact him or her to get further details on augmented products.

Use Cases and Examples

By now, one has learned that there are two typical ways of how augmented products are implemented, either by using a widely adopted smartphone or tablet, or by using wearables, such as Microsoft HoloLens. In this section, specific examples are provided broken down into subcategories: interfaces, digital twins and simulation, quality control applications, contextual information access, and operator instructions. The main focus is on AR interfaces and digital twins because all other examples readily follow from the application of these concepts.

Interfaces

As it has already been discussed in previous sections, interface design and implementation are going to be one of the most exciting areas of augmented products because with AP, one has the option to make various interactions with digital twins as natural as possible for the user. Recall, that the user interfaces function through the following means:

Gestures. In case of mobile devices, gestures are mostly associated with a touchscreen. However, for head-mounted displays, gestures, and actions in the space right in front of the user are made possible. An example of that is provided in Figure 7.

- Voice commands. The user instructs the device used for the implementation of the augmented product to perform a certain action. For example, the user can issue the command “record video” to Microsoft HoloLens 2, and the device will then start recording a video clip of what the user sees ¬– including the augmented objects, or holograms.
- Knowledge about the surrounding environment. This does not directly lead to user interactions but is a necessary part of an interface. The device providing the AR experience must be aware of the surrounding environment to add artificial objects, digital twins, etc., to it. There are several ways that this can be achieved.

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- The most pursued one, obviously, is the intelligent approach whereby the device, using smart algorithms, recognizes the environment, its structure, surfaces, and classifies the objects therein. An example was already mentioned with the animated artificial husky shown in Figure 2.
    - On the other hand, this is still a bit tricky to implement in general due to high computational burden on the device. Hence, the second option is placing physical markers into the real environment. An example of that is shown in Figure 8.
    - Depending on the set up of the environment that should support augmented reality, another possibility is to use, e.g., a dedicated tracking device, such as the HTC Vive Tracker that essentially serves as the marker in the previous option.

When it comes to interfaces, there are lots of opportunities for implementing useful interactions based on user experiences. For example, in Figure 11, resizable spheres are used as user interface elements. The diameter of the spheres encodes the information about the influence of certain parameters related to the performance of the liquid level regulation process. By considering the difference in the relative size of the spheres, the user can learn to relate the scale difference to performance.

Figure 7: Example of a user interface implemented in Microsoft HoloLens 2. The user is manipulating a hologram ¬– essentially a digital twin ¬– of a red chair.

Source: https://www.be-terna.com/insights/microsoft-hololens-2-mixed-reality-headset-designed-to-get-work-done

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Figure 8: The smartphone quickly identifies a marker placed into the real environment and inserts a model of a house to the marker. Obtaining the location and orientation of the marker is a relatively inexpensive operation and can be easily performed offline without having access to cloud computing.

Source: https://www.queppelin.com/webar-with-image-marker-detection/

Digital twins and simulation

In this chapter, digital twins have already been discussed at some length. Recall the example of the husky dog in shown in Figure 2. The fact that it is so easy to insert an artificial entity into the surrounding environment using a smartphone hint at the potential for more useful applications ¬– indeed, in much the same way as a user can insert a husky into their home, it is also possible to insert pretty much any subject or object anywhere. One simple yet insightful example is the possibility to, e.g., preview living room furniture before buying it. An example of that is shown in Figure 9. This, of course, means that there are digital twins available for the furniture which are actually quite easy to make as the manufacturers have the blueprints. Changing upholstery materials in the digital twin domain is very easy as well. With the current generation of digital technology, it is possible to create a faithful reproduction of almost any material.

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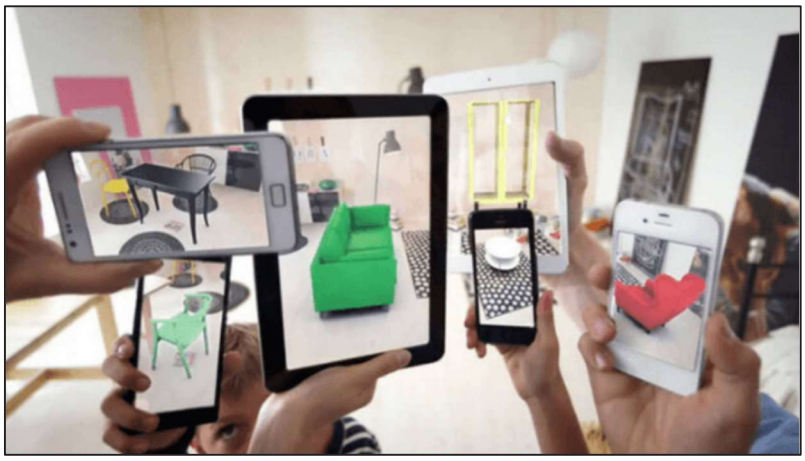

Figure 9: Use a smart device to place a piece of furniture into your living room to see whether it fits your decor before purchasing it.

Source: https://bevel.space/mobile-augmented-reality-in-aec/

The same approach can be taken with industrial applications. In the same way, digital twins of industrial manufacturing machines can be virtually placed into real environments. This allows to plan the manufacturing floor of an industrial complex and is thus rather beneficial for industrial users as well.

Depending on the device, incredibly high-fidelity augmented experiences can be had with head-mounted displays, such as Varjo XR-3. In Figure 10, a snapshot from the video of the Volvo demo for Varjo XR-1 head-mounted display is shown. The digital twin is highly detailed and thanks to the "human eye resolution" fidelity of the HMD, this level of detail can be fully appreciated. For this very reason, the same family of XR devices also work really well for all sorts of simulations including flight simulators.

Another example of simulation is the actual simulation of industrial processes. A lab-scale example is shown in Figure 11. Again, Varjo XR-1 head-mounted display is used here. The idea is to tune a typical industrial PI-type controller for the purpose of efficient regulation of liquid level in the top tank. The digital twin is displayed in augmented reality right next to the actual device in the real environment. The user can observe how changing the parameters of the controller reflects on the digital twin and at the same time on the real system since the two are directly connected. It is perhaps not hard to imagine how this can be scaled up for industrial purposes in the area of advanced supervisory, control and data acquisition (SCADA) applications.

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Figure 10: A high-resolution digital twin of a Volvo car model appearing, layer by layer, before the user of the Varjo XR-1 head-mounted display in a real environment. The user can enter the vehicle and get transported into a different location.

Source: https://blogs.unity3d.com/es/2019/09/09/showcasing-the-worlds-first-photorealistic-mixed-reality-demo-by-varjo-and-volvo/

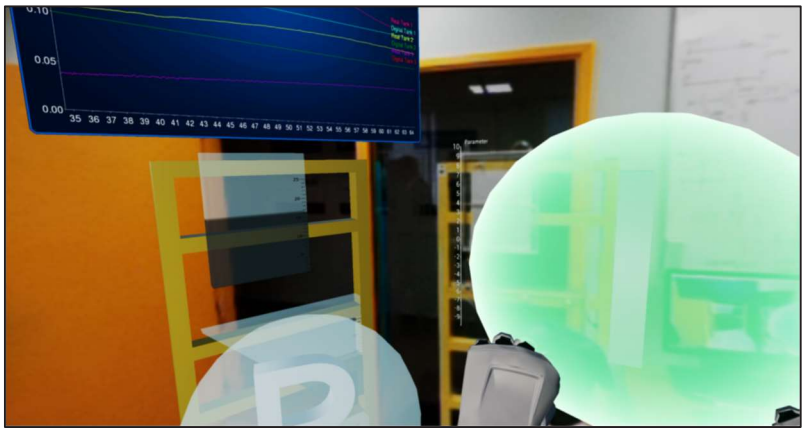

Figure 11: The user directly influences the controller which is responsible for liquid level regulation in the laboratory model of a multitask system[7] [7].

(A video is available https://www.youtube.com/watch?v=KEPo06hiZgk)

To conclude this subsection, a few encouraging examples that are specifically addressing augmented manufacturing processes are provided.

Obviously, the example in Figure 10 is not the only one of the various automotive applications of augmented products. AR works very well in manufacturing. Consider the example depicted in Figure 12. Here, using a Microsoft HoloLens, the engineer is able to quickly work on a

[7] S. Jeršov and A. Tepljakov, "Digital Twins in Extended Reality for Control System Applications," in *2020 43rd International Conference on Telecommunications and Signal Processing (TSP)*, 2020.

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complex mechanical part thanks to useful overlays containing instructions on how to assemble or perform maintenance on the given part.

Figure 12: Microsoft HoloLens used in a production process at BMW. The digital twin serves here as a guide for the engineer.

Source: https://roboticsandautomationnews.com/2019/07/09/bmw-highlights-application-of-virtual-and-augmented-reality-in-production/24450/

One important area where the application of augmented products is robotics, including manufacturing, assembly lines etc. An example of a corresponding augmented product is depicted in Figure 13. The complete procedure leading to this example is as follows: (1) An engineer creates a robot in Autodesk Fusion 360. (2) The space for the robot can be chosen and robot placed into the AR environment. (3) The robot and its functions are tested for compliance with the intended application.

Figure 13: The industrial designer or operator can build robots for different applications using a modular kit with Autodesk Fusion 360. The robot can then be placed into the intended space in AR and tested.

Source: https://qfxspeak.com/2016/01/06/hololens-design-designers/

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Quality control applications

Some good examples of augmented products in industry can be found in the area of quality inspection. Figure 14 shows an example of such an application where printed circuit board assemblies are concerned. The operator can use Microsoft HoloLens head-mounted display to quickly analyze the assembly and troubleshoot any detected problems.

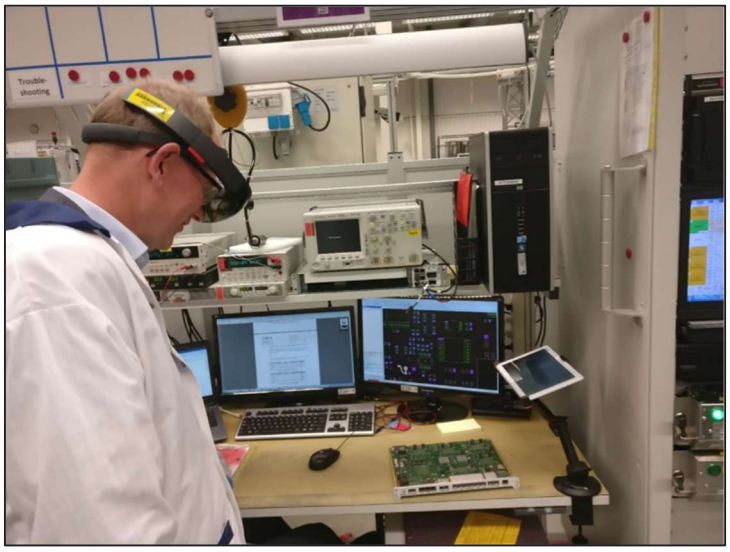

Figure 14: Printed circuit board check in AR using Microsoft HoloLens.
Source: https://www.ericsson.com/en/news/2018/1/5g-manufacturing ¬– tallinn

Some additional examples can be found in the paper[8] [8].

Contextual information access

Augmented reality works really well for accessing contextual information on the factory floor. Assuming the AR implementation can make sense of the surrounding environment and as long as it has a constant internet connection, advanced operator assistance can be implemented as both mobile-based solutions and in head-mounted display applications.

In Figure 15, an example is shown where the operator, using Microsoft HoloLens, can navigate several windows showing relevant information. In the same way, information can appear before the user in relevant locations while the user traverses the factory floor.

[8] D. Segovia, M. Mendoza, E. Mendoza and E. González, "Augmented Reality as a Tool for Production and Quality Monitoring," *Procedia Computer Science,* vol. 75, p. 291–300, 2015.

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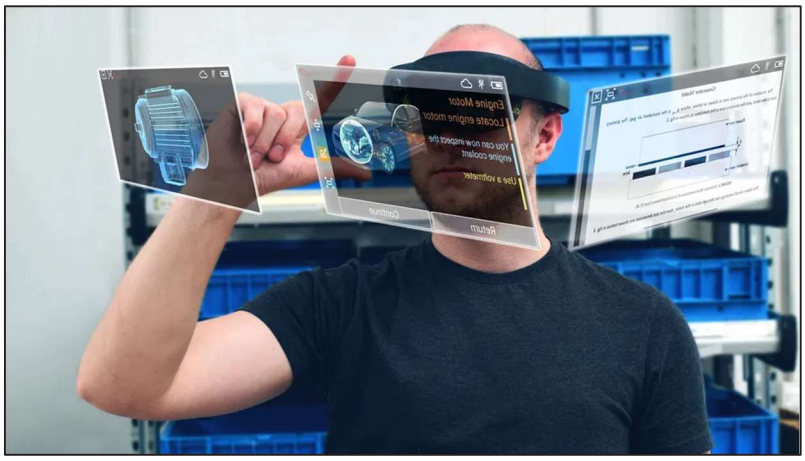

Figure 15: Using Microsoft HoloLens 2 to navigate through workplace data using natural gestures.
Source: https://csengineermag.com/ubimax-launches-frontline-workplace-mixed-reality-for-microsoft-hololens-2/

Operator instructions

One of the more prominent areas of AR applications, operator instructions can be implemented in a variety of useful ways. In Figure 16, an example with a tablet-based AR solution is shown. The technician receives instructions regarding electrical test of a given system.

Figure 16: Technician instructions for testing an electrical system.
Source: https://helplightning.com/

Head mounted displays have the significant advantage of having the user's hands free to perform natural gestures, as discussed in the "interfaces" subsection. So, with augmented reality, this can lead to efficient display of operator instructions either on top of a real-life system or using a digital twin. The latter situation is depicted in Figure 17.

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Figure 17: Operator instructions for checking a certain system in augmented reality.
Source: https://augmentit.ch/hololens-2-ar-applications-for-more-efficiency-in-companies/?lang=en

Obviously, remote assistance is another important area that benefits from augmented reality. This can work with both smart devices and head mounted displays. An example of the latter case is depicted in Figure 18.

Figure 18: Example of augmented remote assistance in the maintenance of an electrical system.
Source: https://next.reality.news/news/15-remote-assistance-apps-driving-enterprise-sector-augmented-reality-from-hololens-iphone-0198955/

Conclusion

As it has been shown in this chapter, future business for augmented products is vast and rich in different opportunities. With Industry 4.0 applications growing in number due to the rapid evolution of technology, augmented products through the development of digital twins will clearly be ubiquitous.

Hopefully, by studying this chapter, the reader has amassed a multifaceted understanding of augmented products, the corresponding market, and the different consumer and industrial applications.

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[8] D. Segovia, M. Mendoza, E. Mendoza and E. González, "Augmented Reality as a Tool for Production and Quality Monitoring," *Procedia Computer Science,* vol. 75, p. 291–300, 2015.

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Developing Augmented Services in manufacturing SMEs

Chapter 03

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3. Developing Augmented Services in manufacturing SMEs

Authors: Carl Vogler and Philipp Zenker, 3DQR GmbH (Germany)

Introduction

Augmented reality opens up special advantages and opportunities in the field of installation and service. Not only can existing processes and technologies be expanded to increase efficiency or reduce costs, but new processes can also be created. For manufacturing SMEs, augmented reality technology offers a great opportunity to gain a competitive advantage and stabilize their market position using AR solutions.

But first Installation and Service have to be defined to see what exactly can be done to improve the processes. The aim of integrating augmented reality is not to add extra steps to existing processes, but to make processes more intuitive and clearer. The following text discusses some ideas and solutions for this.

Installation (VDI 2860)

Installation differs according to VDI 2860[9] in primary and secondary installation. Primary installation refers to all handling and joining processes that are necessary to create an assembly from individual components, while secondary installation includes all processes that support the primary installation but are not absolutely necessary, like testing and adjusting but also handling processes that are not immediately connected to the joining process. In the field of installation augmented reality can streamline the secondary branch by reducing the number of unnecessary actions, but it can also be a visual aid in the primary installation and reduce the times part of manufacturing.

Service

Service is designed to ensure that the functionality of equipment and resources is maintained or restored. It can be broken down into four subcategories, each of which can benefit from the use of augmented reality:

Inspection: Inspection is used to obtain an overview of the technical condition of wear parts but also of settings, measurement systems and the overall condition of the technical equipment. With augmented reality the person inspecting the machines can be shown the optimal condition of the parts and by this judge the

[9] VDI-Gesellschaft Produktionstechnik (Hrsg.): VDI-Richtlinie 2860. Montage- und Handhabungstechnik. Beuth-Verlag, 1990.

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overall condition, or other information can be placed directly in this person's field of view which help to optimize the process of inspecting.

Maintenance: All maintenance tasks include delaying the wear and tear of equipment, i.e., both cleaning work and the replacement of wear parts and operating fluids such as oil, filters or cooling water.

Repair: The term repair includes both the replacement of defective parts and the addition or rearrangement of components in machines and equipment

Improvement: Improvement includes all measures that result in an increase in effectiveness or reliability.

With maintenance, repair and improvement augmented reality applications always can be a visual aid to workers, whether it shows open tasks and guides the operator on a more abstract level, functions as a communication tool between workers for support or give a step by step in depth guide that shows what

Figure 19: An engineer is provided with AR support during
Source: https://as2.ftcdn.net/jpg/01/88/15/87/500_F_188158708_JT2JtMR4XbxlOPmS8ywMwdUF71UK2rNB.jpg

actions are necessary on a 3D model of the machine that is to be worked on.

In the whole area of service associated to augmented reality the term remote support comes in mind. In remote support solutions an expert would not be physically present but rather give instructions to a worker of the SME and the worker would run the service process under the expert's guidance. Augmented reality is very useful in this area because on one hand the expert can track the workers actions, on the other hand the worker can be visually guided which makes the instructions more easily understandable.

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Opportunities

Comparative Effectiveness of Augmented Reality in Object Assembly

People often talk about the advantages of augmented reality without being able to prove them concretely. Service technicians often have to work on a wide variety of equipment, and every now and then, one of them may not have been repaired for a long time or may never have needed to be repaired by that technician. Why would it be so much better to build or repair something with the help of augmented reality? Couldn't a technician just use a printed manual, or view a model of the machine on a laptop? A scientific paper of the Michigan State University[10], however, provides conclusive evidence with a simple experiment. They compared an object setup using augmented reality and three other media-based instructional methods: a printed manual, a monitor-based display, and utilizing a head-mounted display. All participants in the study had to recreate an object from Lego bricks using one of the previously mentioned instruction methods. A between-subjects design was selected, i.e., each participant tested only one of the four design methods. The dependent variables included task completion time, error rates, and perceived mental workload. The first variable, time, showed slight differences in the average minutes taken by the participants. Printed Manual (14:24); monitor-based display (11:25); head-mounted display (11:08); and finally, augmented reality headset (10.39). However, there were clear differences in the errors between AR and the other assembly methods. The number of errors was for Printed Manual (9,3); monitor-based display (8,4); head-mounted display (9,5); and augmented reality headset (1,6).

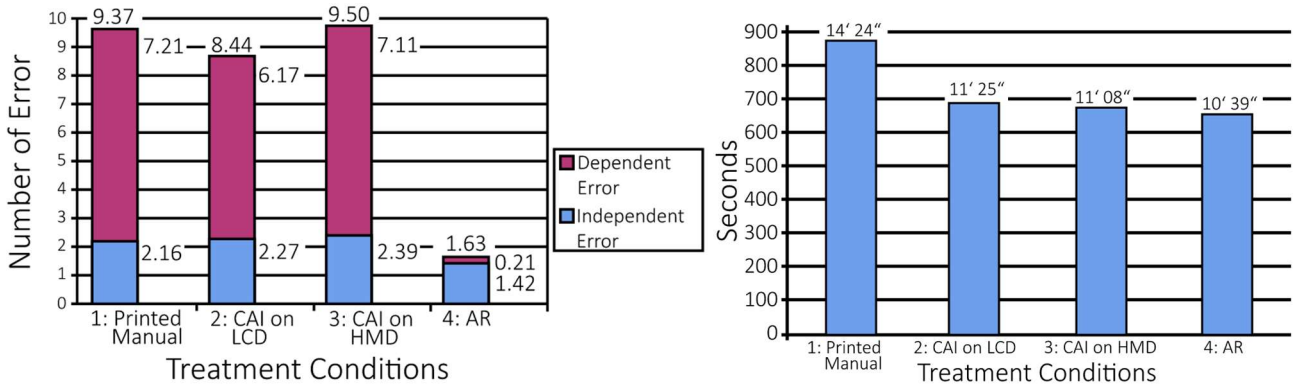

Figure 20: a) Average number of errors in each treatment; (b) Average time of completion in each treatment
Source: https://doi.org/10.1145/642611.642626

[10] Tang, A., Owen, C., Biocca, F., & Mou, W. (2003, April). Comparative effectiveness of augmented reality in object assembly. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 73-80).

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Perceived mental workload was measured using the NASA TLX (Task Load Index) rating, with a low score (0) indicating little stress and a high score (20) indicating a lot of stress. The perceived workload of the method was as follows: Printed Manual (13,3); monitor-based display (12,2); head-mounted display (11); augmented reality headset (10). This experiment illustrates in a very clear way that augmented reality has clear advantages, especially in the avoidance of errors. But the advantages in terms of time and mental workload are not to be neglected either. For augmented assembly and services, this means that repairs can be carried out by non-experts with the help of detailed step-by-step instructions.

Treatment Condition	NASA TLX Rating
1: Printed Manual	13.3 / 20
2: CAI on LCD	12.2 / 20
3: CAI on HMD	11.0 / 20
4: AR	10.0 / 20

Table 1: Average score on NASA TLX rating in each treatment.
Source: https://doi.org/10.1145/642611.642626

Augmented Reality for Factory floor planning

Modern manufacturing facilities often face short-lived product cycles that mean factory floors often need to be reconfigured. It may happen that a new machine must be integrated within an existing production line. Although the dimensions are known in advance and probably also the connections, the complete picture only emerges when the machine is on site. However, if the machine can be visualized on site in advance with augmented reality, all conceivable problems can be eliminated before the machine even arrives. This process ensures a smooth rebuild, which avoids long downtimes of production facilities. Essentially, it is a matter of adapting manufacturing processes to the new conditions as quickly as possible or planning new manufacturing processes in such a way that they produce the required results right away. AR can be used in the following areas: Line planning, product evaluation, workplace design, process evaluation and process support. A scientific paper that provides a good summary of this application area is "Augmented Reality for manufacturing planning" by

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Doil et al.[11] Instead of planning on paper and on a PC screen as usual, they propose to place virtual equipment and robots directly in the hall with an HMI.

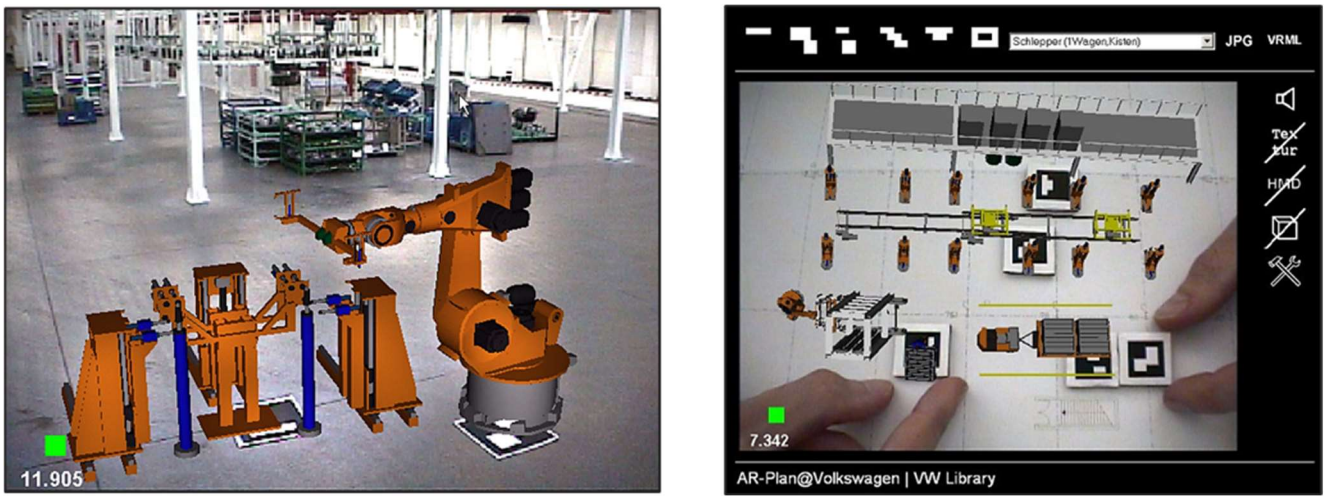

Figure 21: (a) Visualization of virtual robots and machinery in a plant-environment; (b) System-up AR-Plan.
Source: https://doi.org/10.1145/769953.769962

Display on the factory floor: Nowadays, 3D data exists for every modern working device. These can be transferred to an augmented reality application without much effort. Once the entire factory has been built virtually, various problem points can be identified in advance. Is there enough space for safety clearances, are connections available? These questions can be clarified directly with good visualization. At the same time, AR is perfect for measuring distances, provided the hardware is precise enough. This ensures that everything is displayed correctly.

Table-based planning: Once the distances and positioning of the machines have been determined on a real-world scale, more in-depth planning on a smaller scale is quite easy. Individual elements can be easily moved in a tabletop model using markers assigned to them and then viewed in detail using AR.

Possible routings for starting and implementation

Augmented reality is an application that must be carefully integrated into existing processes. Depending on the application area, the integration of AR is complex. Before you start using an AR application, you should first ask yourself the following questions:

- Which part of the manufacturing process can benefit from AR?
- What exactly do you want to augment with AR?
- What kind of AR application is needed for that?

[11] Doil, F., Schreiber, W., Alt, T., & Patron, C. (2003, May). Augmented reality for manufacturing planning. In Proceedings of the workshop on Virtual environments 2003 (pp. 71-76).

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- How does this improve workflow or efficiency?

Step 1: In the service area, AR can be integrated into operations in many ways. However, without a problem to solve, it is not recommended. Examples of such problems can be a lack of qualified workers or poor training. However, problems do not necessarily have to be related to employees. It can also be due to the fact that a product is too complex, or a custom-made product, which has many special features. As written in 1.1 and 1.2 Augmented Reality solutions can be a guidance or another form of visual aid in the manufacturing, installation, and service process. Also Augmented reality can act as an interface in IoT to make it easier to visualize and handle the huge masses of data.

Step 2: After identifying where AR will be used, it is important to get all parties involved. You should make sure that you don't build the AR application from the top down. Ultimately, for example, it is the technician in the field who will be using the application, so his input is especially important. But it is just as important to have AR experts in the team who already have experience in this field.

Step 3: It is important to set small goals. If you try to integrate AR into every aspect of your business, success is hard to guarantee. Therefore, find an aspect that you want to expand with AR, i.e. a product or service. If you succeed there, it is much easier to replicate that success in other aspects of your business. One indication of where to start might be which processes have the most potential for optimization. It is most likely that the greatest ROI will be generated here, so that a successful pilot project can be used to continue implementing augmented reality solutions to increase the profitability of the company.

Step 4: After clearly defining what the goal of the application should be, it is important to choose the right hardware. Is the view through the smartphone or tablet sufficient? Or does the user need to have his hands free to use a tool? In this case, a headset or glasses are recommended, but they are significantly more expensive to purchase. In any case, it should be noted that the hardware can be used in the long term, since AR projects are constantly evolving.

Step 5: After the project has been successfully implemented, it is important to continue to monitor it, as many aspects only become apparent through experience with hardware and software. Continue to customize the user interface or expand the project. Here it can be especially useful if the project is built on a platform that can also be operated by people without programming knowledge, since in many cases these are also the actual users.

ROI: Logically, the return on investment of augmented reality applications cannot be stated in general, but the ways in which ROI is generated by augmented services can be described. In short, the return on investment of AR in assembly and service results from increasing effectiveness and reducing costs.

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ROI generation from process optimization: Assembly processes and services can be significantly optimized using augmented reality solutions. The use of AR allows a computer support of the employees and, this can reduce downtime and idle time needed for information retrieval and more time can be invested in value-added activities. Remote support solutions with augmented reality can also increase equipment and system reliability, as in the event of a defect, an expert can be called in quickly and easily to guide the employee through the maintenance process. The cost reduction for the journey of the service employee adds up to the reduction of costs due to breakdowns of the systems and machines.

Models, tools, solutions, and applications

Tools and solutions for SMEs

The topic of augmented services can quickly seem overwhelming and scare off interested potential customers, because where do you start? Simple AR instructions offer an easy way to get started. These can be used for maintenance work as well as for machines that are used by trainees. All it takes is a marker placed in the right place to start the corresponding scene. This scene can contain an animation showing how to maintain a part, or videos and informative texts to explain the operation of a machine. In this way, trainees can work independently without being constantly supervised by an experienced employee, who can then pursue a value-adding activity. Both the hardware costs for a tablet and the software costs are manageable here and should not be a hurdle for a healthy business.

Available Hardware

Augmented reality hardware requires a complex range of sensors. Therefore, modern smartphones are the most widely used hardware solution. However, major companies have been working on dedicated AR hardware for a few years now so that users don't have to hold a smartphone in their hands all the time. Whether AR glasses or smartphone (tablet), both categories offer a wealth of choice.

Smartphones and Tablets: Smartphones and tablets are generally equipped with comparable hardware components across manufacturers and have long been used as a platform for AR apps due to their high distribution in the consumer market. Among smartphones and tablets, the iPhone 12 Pro and iPad Pro 2020 are the best hardware solutions thanks to an integrated LiDAR sensor. This enables the devices to precisely scan the immediate environment and thus place AR scenes at the correct location.

AR glasses and Headsets: Popular aids are the so-called augmented reality glasses. Providers such as Epson, Microsoft, Vuzix and Irisstick have already addressed this issue and developed the first models. They are used, for example, in warehousing and logistics, in assembly and product development, and in medical technology.

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Data glasses do not yet have as many functions and possibilities as a smartphone. But in the future, data glasses will be used mainly by body language, speech, or gesture. Control by simple looks is currently still being worked on. This will drive forward to a more intuitive development of the operation of some technical devices. Data glasses will be able to easily merge the virtual world with real world perception. A wearer of data glasses has the advantage of always having their hands free. This makes the glasses very practical at work.

3D Models

Every AR application is based on 3D models. In the area of maintenance and service, it is therefore extremely important to have each device as a 3D model in order to overlay it on its real-world counterpart and to supplement it with important information or work steps. A simple method to create these models is a 3D laser scan. A laser scan does not provide all the details of a device but is anyway only needed to have an orientation in the AR scene. This means the 3D model itself is not visible and only serves to place important information and visual markers correctly.

Digital Twins

One technology that perfectly complements AR is the digital twin. Especially at the complexity level of industrial plants with the need for optimized process control, the digital twin is becoming increasingly important. For SMEs, control is very important, as any machine cannot be replaced quickly, and a new machine is always a well-considered investment. This digital replica of every real-world object contains, in addition to the 3D CAD data, various other information such as the properties of individual components or materials used. However, a major problem in using this data is easy-to-understand visualization. This is where augmented reality comes into play again, as nothing would be more intuitive, i.e., to look at a device, or a part of it, and immediately have all the important data about it in view.

Incorporation of CAD Data to Augmented Reality solutions

CAD (Computer-aided design) is used to create digital design models of various types, which provide the information from which the desired product can be manufactured. This type of design is often associated with being particularly helpful in noticing and correcting errors early on. Often, however, the 3D data just lie around after the end of the design process. However, they can be extremely useful for creating richly detailed and interactive AR scenes.

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Use-Cases

DIHK

DIHK-Bildungs-GmbH develops products and services for vocational education and training on behalf of the individual chambers. Among these are also the textbooks and practice materials for IHK exam preparation. In a collaboration with 3DQR, teaching materials were provided with 3DQR codes to make the educational activities more vivid and to support the participants visually and interactively in the learning process. With augmented reality, we had the opportunity to create a completely new form of learning, with which the trainees can also better prepare for his seminar at home. To access the AR scenes, the apprentice only must open the relevant page and can then scan the 3DQR code using his smartphone or tablet. Then they see the virtual scene in front of them, which helps them better prepare for the lesson. Our goal was not to do away with printed teaching materials, but to develop a modern supplement for better visualization of processes. An image printed on paper is often only a means to an end and can only represent in a simplified way what happens in the three-dimensional space. With an animation that floats directly above the textbook, however, any process, no matter how complex, can be represented without a break, i.e., a change of medium. Going one step further this solution could not only be implemented for training and continuing education materials, but information could be retrieved directly from the machines in this way. This would reduce unsafe actions, but also allow less trained workers to operate the respective machines without having to search for information on operation and parameter settings. The time lost in searching for information could be invested in value-adding activities.

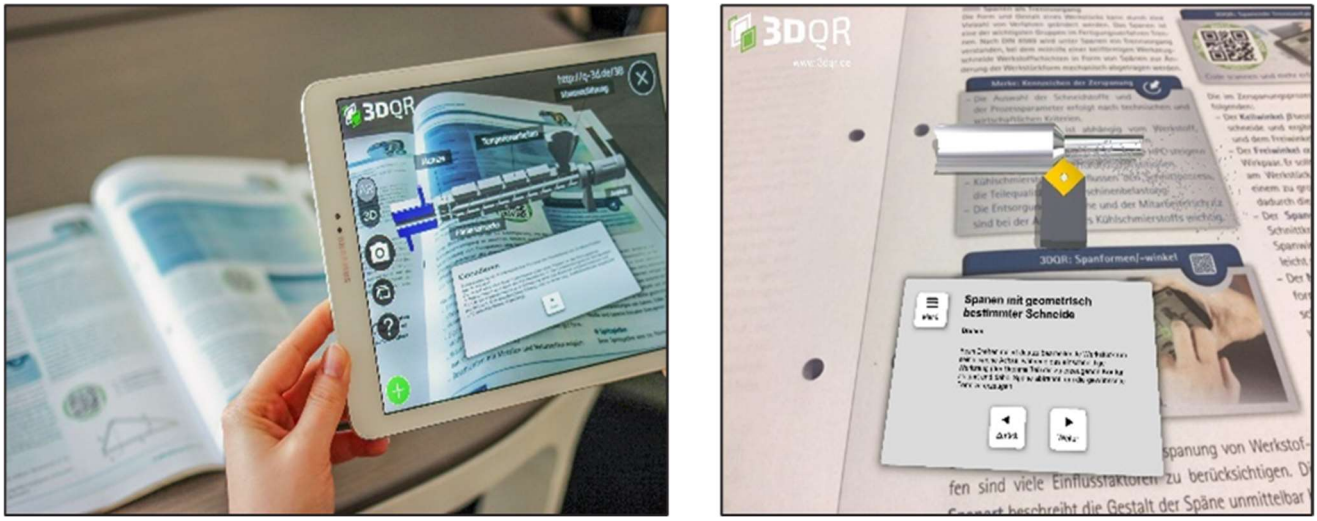

Figure 22: DIHK Textbook
Source: 3DQR

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Remote support in maintenance

Smart augmented reality-based instructions are particularly suitable for maintenance work that has to take place at regular intervals. In an IOT solution for a medium-sized German company, 3DQR created such instructions. In Internet of Things applications, many parts have data interfaces to forward measured values and other data so that they can be accessed centrally. These connections must not be damaged during the replacement of wear parts and must be restored after replacement. This sensitive step of the maintenance process makes the whole task more complicated and happens in several steps. The augmented reality support for this task was a solution that displayed all the steps on the digital twin and after completing one step, the user could move to the next instruction. With the help of the digital twin, users could see exactly which cable connections needed to be made and when, which components needed to be handled with special care, but also which safety precautions needed to be observed. Augmented reality can speed up processes of this kind and reduce the error rate for untrained personnel.

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Conclusion

If you take a closer look at augmented reality, it's easy to imagine a future in which everyone wears glasses that allow them to interact with virtual objects. A colleague who is in another country could be standing right next to you and give helpful tips, or a defective machine can tell you at a glance exactly where the problem lies. All of this is already possible, but not yet in the way a science fiction story would portray it. The first small and medium-sized companies to integrate augmented reality into their processes will have such a significant advantage from this technology that it will be difficult for other market players to catch up.

The technical implementation still lacks reliable hardware that keeps the user's hands free. However, anyone who is satisfied with a smartphone comes very close to this scenario. The new 5G mobile communications generation also ensures that the vision can become a bit of a reality. 5G makes it possible to transmit very large amounts of data very quickly, as is necessary for many AR and VR applications.

Already at this stage, augmented reality is a sophisticated technology that is doing great things in the here and now. Whether it's planning or installation, maintenance or repair, remote service or maintenance training, AR makes many things faster, easier, more collaborative. They help to make processes more efficient, reduce costs and increase quality, which is why an investment in this technology, as long as it is well planned, will always be worthwhile.

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How Virtual and Augmented Realities can support the design process in manufacturing SMEs

Chapter 04

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4. How Virtual and Augmented Realities can support the design process in manufacturing SMEs

Author: Ignace Martens, Katholieke Universiteit Leuven (Belgium)

Introduction

Thanks to the rapid evolution of AR/VR technologies, the design of new products can be significantly more efficient nowadays. This article shows how AR/VR can be implemented step by step in a product design process, what concrete benefits one can expect and it allows to estimate the return on investment.

The Hasso-Plattner Institute of Design at Stanford is considered as the leading university concerning Design Thinking. They proposed following 5-stage Design Thinking model which is followed by most designers: Empathise – Define – Ideate – Prototype – Test ([5] Liu et al., 2011). This model is very useful to solve complex ill-defined problems, by understanding the human needs of a target group of people, by defining the problem in a human-centric way, by creating a lot of alternative solutions and by developing and testing a prototype.

Empathise

The first step in new product design is to understand the problem or opportunity. Try to empathise with the target group, to understand their thoughts, their feelings, motivations, and needs, to see the world through their eyes. In this stage, you should interview the target group, observe them and listen to them. What solution is currently used and what are its shortcomings? What are people bothered by?

Define

In this phase, the information gathered in the empathies stage is analyzed to fully understand the core problem. Following questions should be answered in this stage: What is the problem to solve? What is the target group? Why is it important to solve this problem? What are the requirements? What are the limitations? Problem definition is very important to direct all design efforts to the defined design goal.

Ideate

The design challenge is to create a design that meets the needs of the target group and matches the design language and product DNA of the overall product portfolio. To achieve this goal, designers brainstorm in team and try to find as much alternatives as possible. To generate new ideas, the acronym SCAMPER (Substitute, Combine, Adopt, Modify, Purpose or Put to another use, Eliminate, Reverse or Rearrange) can be used, initially described by educationist Bob Eberle in 1971. Nowadays, this design process step can also be supported by

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AR/VR design software. Since [1] Abidin et al. (2011) states that a shape aspect assessment is done better in a 3D view than in a 2D view, this software should have morphing functionalities to change shapes.

Prototype

Create and build a proof of concept, a mockup, a prototype, a scale model or maquette. It allows to have an impression of how the final product will look like and how it will perform. It proofs that the concept will work. It also allows to test user experiences. Physical prototypes have a big drawback: they are costly and very time consuming since parts have to be ordered, manufactured and assembled manually. In addition, sometimes several prototypes must be made. Nowadays, a lot of CAD/engineering software programs allow to make virtual prototypes that can be viewed in AR or VR.

Test

Does it work? Is this the desired solution to the problem? Does it meet the original design challenge objectives? What could be improved? Let the target group assess the product. Collect feedback from them. Discuss how the design can be improved. Make revisions and draw new designs.

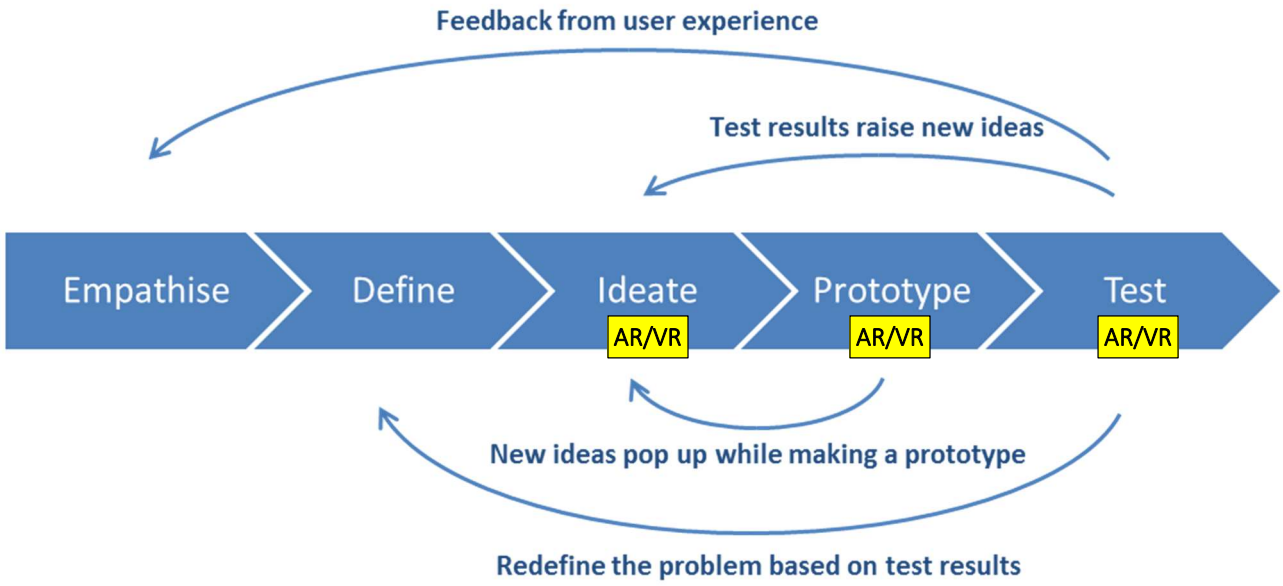

Figure 23: Design thinking process
Source: Original

So, a design process is a process with successive steps, but it never turns out to be a linear process. It's an iterative process with a lot of permanent feedback loops. One can go through the process individually but there is a high synergetic effect when it is done in team.

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Opportunities

Augmented Reality (AR) makes your design department way more flexible

Traditionally, a designer is sitting at his desk, using a design software and looking at his screen to view the product. Using AR glasses, a tablet or a smartphone, he can experience his design virtually in any physical environment.

Product visualization with Virtual Reality (VR)

With VR, designers from all over the world can work together, as if they are in the same room. They can discuss design issues of the product by looking at it from the outside but also by looking from the inside out! VR is used to scrutinize a product design looking for design flaws. At the same time, VR allows to check in the design phase not only the visual looks but also manufacturability, maintenance and safety issues and ergonomic aspects.

AR can reduce money and time spent on physical prototyping

Nowadays, modern CAD software integrates AR capabilities. Once a 3D design is finished, the designer can view an accurate representation of his design superimposed on the real physical environment. This ability eliminates the need to build several different prototypes. It allows to find design flaws, to check for maintenance-friendliness, to experience daily use, to view how the product integrates in its intended setting and to give the stakeholders a realistic impression of how the product will look like. Most CAD software also allows to control viewer access, to distribute AR experiences to others and to share design data.

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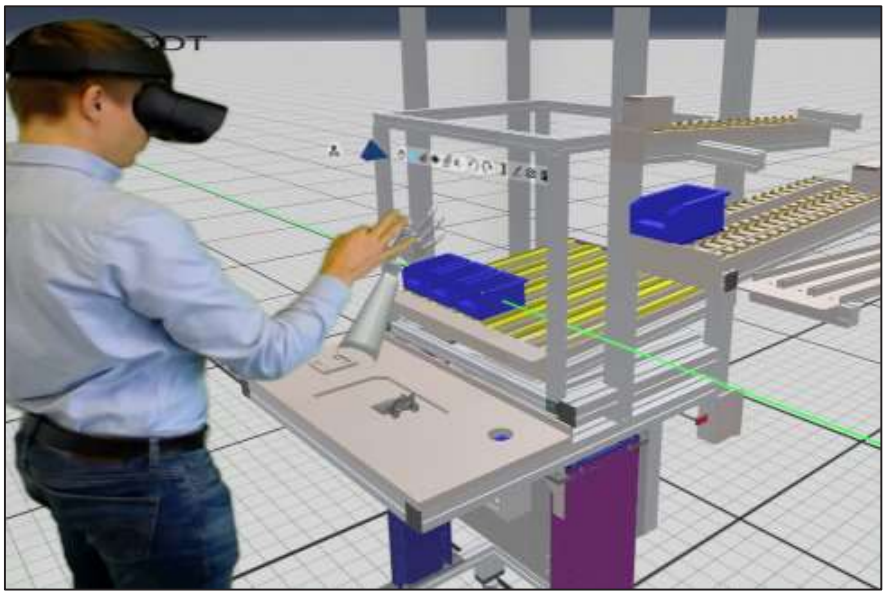

Figure 24: Design review with R3DT
Source: from https://r3dt.com/use-cases/design-review/

Implementing VAM Realities in the design process

The Return on Investment (ROI) of introducing AR/VR technologies in a design process will be different for every SME, depending on the current workflow and cost structure. However, by listing costs and other drawbacks and putting them against cost savings and other benefits of a AR/VR implementation, it becomes easy for every SME to estimate the ROI. Further, an implementation plan is presented based on the principles of successful change management.

Implementation costs and drawbacks

Costs

- Yearly design software subscriptions: < €1000/year (e.g. SketchUp: Desktop and web subscription for Studio version (advanced workflows): $699/year)
- Virtualist (software to build scenes in which one can review designs): €50 per designer per month with 10 watcher guests [8].
- Training costs: additional cost for learning to use the AR/VR Viewer software: 1 day/designer: < €1000/day
- VR headset: < €500 (e.g. Oculus Quest 2 : €350)
- AR glasses: < €2500 (e.g., Vuzix M4000: €2325 and Vuzix M400: €1705)

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Non-quantifiable drawbacks

No drawbacks are reported in literature or by experts except the typical drawbacks of wearing a HMD of which less comfort, short battery life, dizziness and social isolation are the main ones.

Implementation savings and benefits

Savings

- 11 times more design issues discovered with AR/VR than in screensharing sessions [9].
- During the design phase of the new Seat Ibiza, 600 improvements were made long before a single car is built [13].
- For the new Seat Ibiza, VR has led to a 30% reduction in prototype production time [13].
- Reduction of late change requests: average price $5000/request [9].
- Safran, a French aerospace company, built a VR cave for design review meetings and it allowed them to manufacture an Airbus 320neo nacelle in 42 months instead of the expected 60 months while at the same time reducing the manufacturing tool cost with 10%. Their VR cave saved them €300.000 already.
- Lockheed Martin's Emerging Technologies Lead, Shelley Peterson, says that its "satellite operations have used HoloLens 1/Scope AR to reduce Design for Inspection (DFI) by 39% [7].
- Bell has used HTC Vive to cut development time for its new FCX-001 helicopter from an industry standard of 5-to-7 years to just 6 months. While these time and cost savings are impressive, the increased competitive advantage and revenue growth from dramatically faster time to market are measured in the millions of dollars [7].
- Trimble has focused on the use of HoloLens for early identification of discrepancies between design and construction to reduce rework in architecture, engineering and construction (AEC) projects. Aviad Almagor, Senior Director – Mixed Reality and BCI, said that "using mixed reality for early resolution of clashes and coordination issues has saved clients weeks of work, prevented cost overruns, and schedule delays." Trimble has also announced XR10 with HoloLens 2 bringing mixed reality to front-line workers [7].

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Not-quantifiable benefits

SME's that have implemented AR/VR technologies are reporting many advantages of using these technologies in the design process like higher efficiency, better view on how the product will look like and how it will integrate in its intended setting. Earlier detection of design flaws, better insights, easy collaboration between designers/architects/experts/clients/etc. wherever they are in the world, keeping focus of all stakeholders on the topic, faster decision making, much less redesigns, clear communication, sooner project approval and last but not least: higher safety. The safety factor alone can be enough to justify an investment in AR/VR technology due to the cost of accidents both during training and on the job.

And finally, when investments in AR/VR technology can be used by multiple departments or in multiple applications, its utilization rate will be higher and so the ROI will be even better.

Step by step implementation plan

The 8-steps plan by John P. Kotter is a good guide to the successful introduction of AR/VR technologies in SMEs. These change management steps are each translated into the concrete situation of a design process.

Step 1: Create a sense of urgency. Show management successful use cases of AR/VR in new product design, point to the waste generated by the numerous design iterations in the current situation and put their attention on the opportunities for the own design process like e.g., a faster time to market, lower design costs, fewer late design changes and more satisfied customers.

Step 2: Build a leading coalition. It is important that management supports the change process. They must be convinced of the usefulness of introducing AR/VR technologies into the design process. After all, they have to provide the budgets for the necessary investments and without their support, the project will be diluted quickly afterwards. Active management involvement also ensures that other employees fully participate in the project.

Step 3: Develop a vision and a strategy. A vision describes a bright future in which the SME can enjoy the interesting benefits of the AR/VR introduction and where the customers and other stakeholders also experience added value while a strategy describes the way to get there.

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Step 4: Communicate the vision. Use multiple channels and opportunities to communicate the vision. The aim is that ultimately all stakeholders are convinced of the benefits of AR/VR in the design process and that they want the change themselves.

Step 5: Create a broad support for change. Provide training in AR/VR technologies and AR/VR design software to those involved and remove all barriers that prevent people from joining the change process (reporting obligations, promotion criteria, compensation schemes, etc.).

Step 6: Create short-term successes. Start a pilot project in one part of the design department to prove that the transformation to AR/VR supported design is worth the efforts, to keep the bosses on board and as a counterweight to critics and obstructionists.

Step 7: Consolidate the improvements and move on. Show the AR/VR application to the other designers, let them experience the benefits and use the momentum to roll out this technology further throughout the whole design department and beyond.

Step 8: Embed the new way of working in the company culture. Incorporate the use of the new AR/VR tools in the standard work description of the design process and help designers who, for one reason or another, do not use them.

Tools and solutions

Designers use following tools to generate ideas in the design process: mood boards, sketches, morphological maps, scale models and prototypes ([4] Joundi et al., 2020). Software tools available to support the design process can be divided into 3 groups: CAD software, software to visualize CAD-files with AR or VR and 3D paint programs.

CAD software

CAD software is often used to represent already designed ideas ([2] Dorta et al., 2008). Recent versions of CAD software like AutoCAD, Pro Engineer, Solid Works and others are accompanied with an AR/VR file viewer to allow to view the design with a VR headset or with AR glasses. These software programs also allow to make design changes immediately after obtaining feedback from stakeholders.

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Visualisation software

Visualization software allows to visualize an existing CAD file in order to have a view on how it looks, to check manufacturability (especially assembly), to simulate its use and interaction with humans, to assess ergonomics and to detect safety issues. AR applications show the designed product virtually in a physical environment.

Mindesk is a 3D CAD platform that allows to render files from different CAD programs (Solid works, Rhinoceros, Grasshopper,) in real time with Unreal Engine 4. The models can be viewed on different devices (from Oculus, Varjo, HTC,) without the need to export the big files to a HMD.

Some other AR apps to be used to present a company's products with AR, include Wake one XR Showroom, 3DQR Studio, R3DT, Augment, ARki, and Visual Link IT.

Figure 25: AR product visualization with 3DQR

Source: from https://3dqr.de/

Iris VR Prospect and Insite VR Resolve (available for free trial) are examples of apps for architectural design coordination in VR. These tools plug in to existing design software and workflows such as SketchUp, Revit, Navisworks and BIM 360.

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3D paint software

With this software, artists can create 3D art work, view it from the outside but also from the inside. Designers can use this software in the ideation phase for rapid prototyping of design elements.

Tilt Brush allows to paint in 3D with different colours of paint, with different types and sizes of brushes. But you can also choose to paint with textures and even with light and fire!

Gravity Sketch is a 3D design platform for cross-disciplinary teams to collaborate in the same virtual studio from remote locations. It's very useful for 3D sketching, modelling and surfacing, for creating and reviewing designs together. It is a very intuitive application, easy to learn and with a great interface. It is available for Oculus Quest, Oculus Rift and Steam. The app is FREE for individuals!

SketchUp is smart 3D modeling software to visualize design ideas with hundreds of professionally-developed extensions like shading, glazing and daylighting. The software allows to step inside a creation with the AR/VR Viewer (included in every version) to show a design in AR glasses, in a VR headset or simply on a desktop.

Use cases

Digital Twins

Volvo Cars uses Siemens Tecnomatix Plant Simulation to design and improve manufacturing processes in their welding department, paint shop and final assembly building. A digital twin allows to simulate production processes in order to find bottlenecks and to determine expected output. They continuously put effort in both refining and updating the model and in running simulations. These simulations show the influence of all kind of input parameters (like buffer sizes, automation, reliability, line balancing, decision models,…) on work-in-process and on expected output. A digital twin allows to validate a design change before it is physically built. As a result, it gives a company confidence to execute a design plan. In general, digital twins are also used for training purposes (e.g. robots, cranes, elevator trucks, ships, planes,…)

CNH checks manufacturability with Techviz XL

CNH is using Techviz XL (French software), for already 4 years. This software is used to support Design for Manufacturing and Design for Assembly. This software allows to look into 3D

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machine designs delivered through their Team Center platform, to check a design's manufacturability and to detect assembly issues in an early design stage, preventing expensive redesign cycles. The software is used in two ways, using an HTC Vive (single user) or using a projector and a screen while people look at the screen wearing 3D glasses (multi user). Mirroring the HTC Vive is not used because it makes the audience dizzy. The strength of this software solution is that clients all over the world can work together in real time. They display their 3D project immediately from any application on any VR system and without any data conversion. CNH uses Team Center (Product Lifecycle Management software from Siemens) to manage their product designs. The accompanying viewer gets the graphical information from Team Center and renders the 3D model for the VR headset in real time. So with the viewer, designers can look at their design from all sides, even from the inside! Four years ago, this has been the trigger for them to choose for this software together with the affordable price (€100 000 compared to around €400 000 for the most expensive equivalent software from a competitor). At this moment, it is difficult to estimate the ROI of this application. In the past, design engineers made the technical design and after some office operations manufacturing engineers scrutineered the technical drawings, checked the manufacturability and looked for assembly issues. Most of the times the files were sent back to the design engineers to redesign parts. Thanks to this VR application the number of rework cycles has been reduced significantly.

Presenting design alternatives to clients

Virtual city modeling in VR

To get an idea of the look of renovation works in a neighborhood with apartment blocks in Tallinn, a 3D model of the environment has been created using Blender and Unreal 4. The model includes apartment blocks, roads, bus stops, traffic lights, signs, playground, etc. The 3D VR model is based on photos, street maps and physical visits of the area and allows users to have a realistic walkthrough. City architects use such models to try out several design alternatives.

Designing in VR

A German company has developed a platform to use VR in interior design. The application allows to easily change wall colour or flooring options and switch between different kinds of furniture in real time. The benefit of this application is that it supports the customer in making decisions about options he has to choose from and so it shortens the decision process and as a consequence also the whole design process. This technology improves time and cost

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efficiency in the process of making customer specific designs. Traditionally, a customer has to come to a physical showroom and make an appointment with the salesperson well in advance. Now, he can use the application over and over again, from anywhere in the world and at any time, until he has made his final decision.

AR design visualizations on location

For new building designs, before making final design choices, both architects and customers want to know how the new building will look like and how it will integrate in the surrounding environment. Building a scale model of the new building together with a scale model of the surrounding buildings and landscape elements is costly, time consuming and finally it doesn't give a realistic impression of how the new design integrates in the street view. As a solution for this case, AR offers the opportunity to present the design at the actual location in an impressive and visual manner. As an example, an architect can take the clients to the planned building location and present the building to the clients with AR. This can be beneficial for the clients as they can more easily examine the surroundings from different angles and see how well the design fits in the street view. Smartphones, tablets and AR glasses can all be used to present the design.

In these types of use cases, Virtual Reality (VR) is often used to present new product design to clients. However, AR visualizations can have a lower barrier for use, especially for users who do not want to put a head mounted display (HMD) on their heads. Viewing a building for example via a tablet is easy for users who do not have much experience with AR or VR and it requires minimal training and instructions.

Architectural design coordination in VR

During the architectural design of structures but also during the design of made-to-order products, professionals with different backgrounds and many other stakeholders have to contribute to the final concept. Coordinating the consultation between these groups of stakeholders has always been difficult and time consuming. New developments in Virtual Reality (VR) technology now offer interesting opportunities to make this process more efficient and effective. Studying the design together in VR can help identify conflicts and improvement opportunities, which can then be resolved in the design software. The visual and immersive nature of VR makes it easier for professionals from different fields to collaborate and exchange ideas. This kind of Social Virtual Reality can make collaboration more interesting and engaging than viewing the same content on a 2D screen. Users can create text or voice annotations and link them to design objects. This information is then fed

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back to the design software as tasks to be performed. Direct manipulation of design files is already possible in some CAD software such as e.g. the Minsite VR software. Previously, exporting the design file to VR took hours or even days, which significantly slowed down this process. However, recent updates in various software now allow users to export the model to VR in minutes with a single click. This removes one of the main barriers to using VR in design coordination.

Conclusion

2D drawings cause many misunderstandings. Our brain has to form a picture of the design based on different views, sections, measurements and tolerances, and that is not easy. Some stakeholders are not trained for this (clients, authorities, investors,). A 3D representation, on the other hand, shows the design as it will be perceived in reality. AR/VR technologies add another dimension: their immersive nature allows the user to virtually experience the product.

A Capgemini document from 2018 reports that 82% of companies implementing VAM Realities find them to match or exceed their expectations. These companies do not publicize the benefits that they experience with an AR/VR implementation because they want to maintain their competitive advantage for as long as possible. The main question for the application of AR/VR technology is no longer how much it will cost, but how much it will cost if the technology is not implemented! [14].

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How Virtual and Augmented Realities can support business operations of manufacturing SMEs

Chapter 05

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5. How Virtual, Augmented and Mixed Realities can support Business Operations in manufacturing SMEs

Authors: Carsten Domann and Ian Donovan, FHM Berlin (Germany)

Introduction

It is often that companies are overwhelmed or short breathed with the diverse and ever-increasing range of XR technological solutions that can support, assist and enhance the day- to-day operations of companies. This chapter focusses on those solutions that have an impact on business operations. In the context of SMEs involved in manufacturing, the umbrella term Business operations refers to the daily manufacturing operations of a company, the operational processes and practices. These include amongst others the following activities and similar business areas: production processes, machinery operation and functionality, worker/operator practice, process documentation, control and monitoring. Generally speaking, the daily activities of manufacturing processes on the shop floor, and the activities that involve and effect the workers and operators. For business activities that involve, and effect management staff and organisational challenges please refer to chapter 9 of this handbook.

Opportunities

Of the two technology types being dealt with in this handbook, namely virtual and augmented reality, it is augmented reality (and to certain extend mixed reality) that has currently the larger impact on business operations and the areas defined above. Augmented reality is a technology that gives the user an interactive experience of their real-world environment, where the objects that reside in their real world are enhanced by computer-generated information and imagery [12](for an in-depth overview of augmented reality, please refer Chapter 4).

The clear advantage of augmented reality over virtual reality in the context of business operations is its ability to superimpose visual and contextual data onto the shop floor environment using a AR headset (or mobile device such as tablet and/or smart phone), whilst not impeding the visual capacity of the workers/operators, and allowing them to continue to work hands-free and unobstructed. AR also allows for instruction and guidance to be delivered to the workers/operators directly whilst they are carrying out their tasks.

[12] Paraphrase of Wikipedia definitionaugmented reality (https://en.wikipedia.org/wiki/Augmented_reality), 12.04.2021

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From both cases it can be easily deduced that the operative business practice – the generation of value per se - has a new, different – and at the same time technology-oriented and implementing nature from the beginning over various stages: offer, customer side and technical infrastructure. For the sake of completeness, monetary aspects are included[13], for more information see chapter 9.

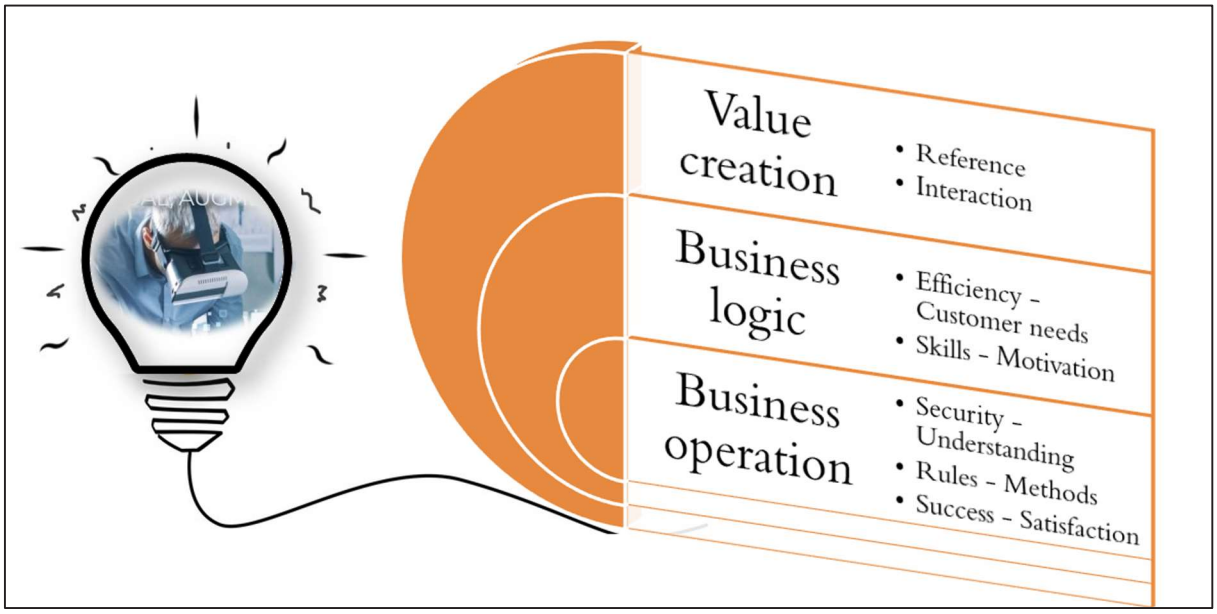

Figure 26: Business Operation with XR[14] #
Source: Original.

Testimonial: Machinery producer in Belgium

The first AR application allows to project operator instructions in a smart glass, using the Iris tick smart glass device with Proceedix software. It is used during assembly and allows the operator to work on the product hands-free. We learned that Iris tick, at this moment, are the only smart glasses that are very comfortable to wear and at the same time are certified as safety glasses.[15]

[13] Adopted from Trott, P. [2017], p. 422
[14] Adopted from: Engelhardt, H. et al. [2016], p. 52
[15] Paraphrased from the VAM REALITIES European Survey Report (Interview 1 from Partner KULeuven)

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Figure 27: Iristick in industrial use
Source: https://iristick.com/

With the availability of real-time and contextual information to the worker/operator in this uninhibition format, combined with the ability to input instruction and operational guidance, there is vast potential for companies to constantly optimise their production process by using Augmented reality technology. Please refer to Chapter 2 and Chapter 3 for a full overview of augmented reality technology.

When considering this opportunity, it soon becomes clear the potential to integrate this technology into numerous elements of the manufacturing process and the different areas of business operations. Consider the technologies potential impact on the following areas, for example:

i. reducing the communication of real-time data and information to the company workforce,
ii. providing instruction and guidance to operators on new work processes steps and new work procedures,
iii. new hire training and on-boarding new employees,
iv. the optimization of work processes and production workflows,
v. increasing worker participation and worker input in the optimisation process,
vi. and finally, the visualisation of operational data such as overall equipment efficiency in real-time and its eventual documentation.

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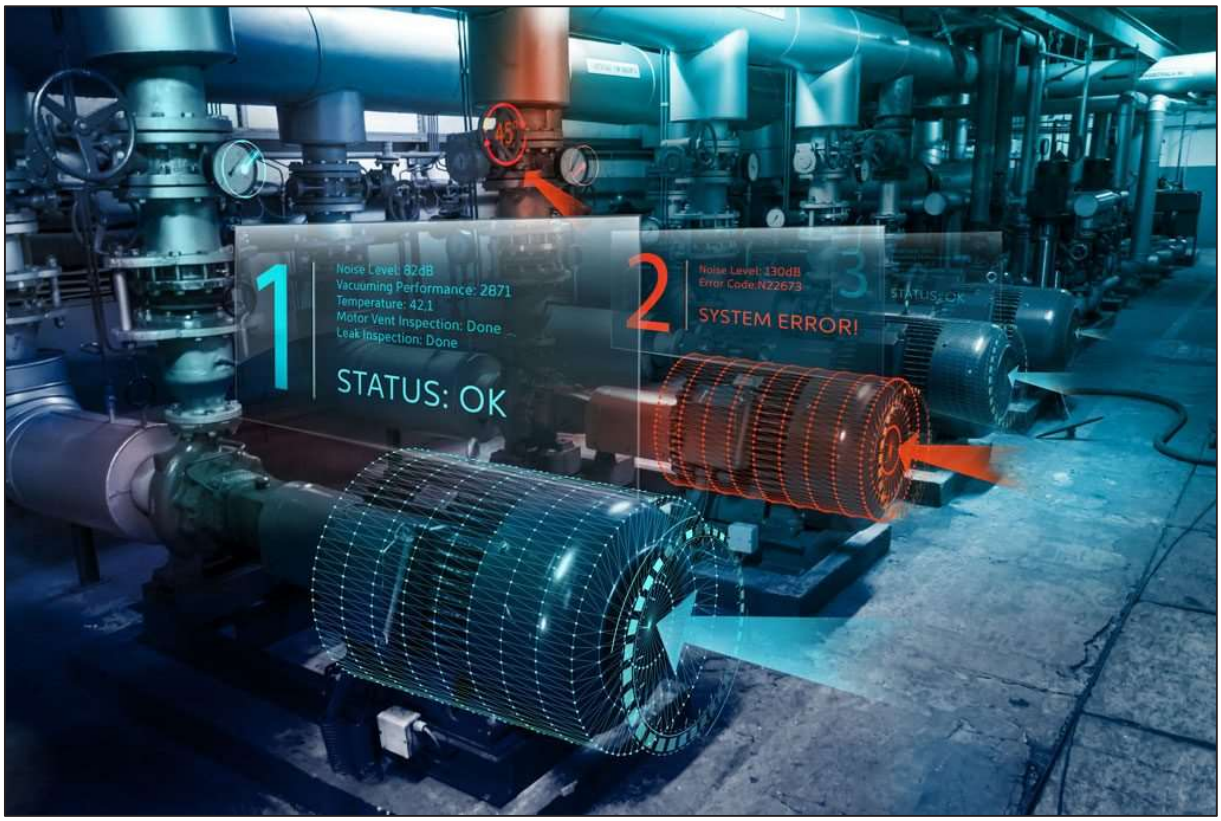

Figure 28: Example Augmented reality real-time updates[16]

For SMEs currently operating Manufacturing Execution Systems (MES), the integration of Augmented Reality Technology is a clear opportunity to enhance this system. MES System provide an insight to key business operations elements such as resource and production process scheduling, execution of production orders in alignment with process control systems, dispatching production orders, overall equipment effectiveness, and the overall collection of data of the manufacturing process. These systems are an integral part of many SMEs business operations.

16 https://www.it-production.com/wp-content/uploads/2018/08/146607_Pumps_MR_Large-1024x683.jpg, 12.04.2021

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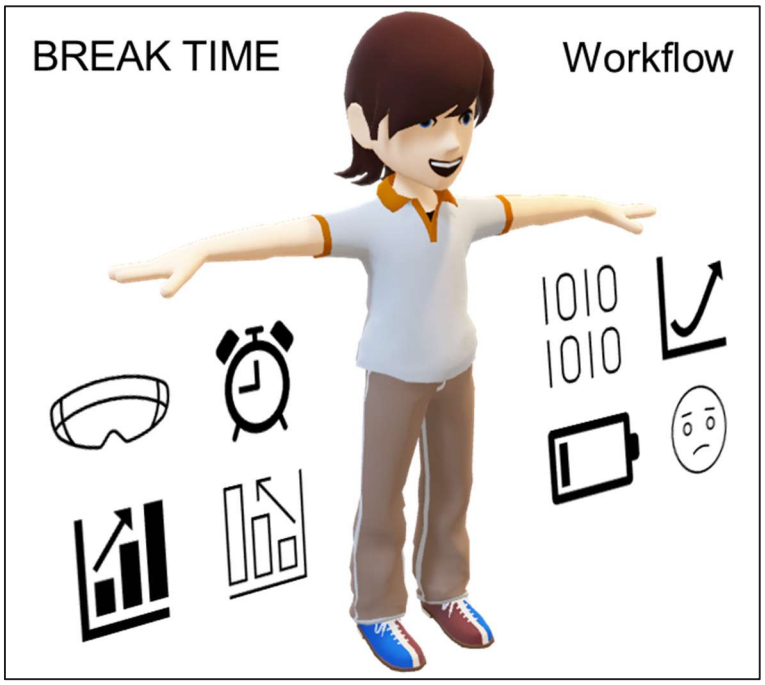

Figure 29: Worker data management
Source: Original

All the data that is available via a modern MES system can be integrated into an AR headset or mobile device and become instantly accessible to all workers/ operators on the shop floor and in real-time. By superimposing a relevant and real-time data flow upon the shop floor via AR, this allows workers/operators to identify potential problems that arise, adjust and react to the information flow, take action and continuously optimise their work and the manufacturing process.

When adopting augmented reality, it is important not to implement the development for a purely top-down approach, it is ultimately the worker or operator who will use this technology as a tool in their daily work and it is critical to engage with these users in order to ensure successful adoption and to gather valuable feedback for amending and making improvements.

Please refer to Chapter 3 Augmented Services in manufacturing SMES for an overview of the process of integrating AR into a company, and a 5-step guide on adoption and what aspects need to be considered when establishing and maintaining.

VR/AR technologies are also beneficial in other areas of business operations such as overcoming the challenges industry suppliers in logistics, storage and Inventory management in companies of all sizes and sectors. Current inventory management systems allow companies to keep track of their products, assets and inventory in storage and warehousing. Firstly, VR technology offers users the opportunity to experience, trial and optimise the workflows and processes being created in warehouse planning before these leave the planning stage. It also allows workers to become familiar with new warehouse planning and new work processes before they are even completed.

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Figure 30: Example of Augmented reality Order picking[17]

Once a warehouse plan is in place, optimise the inventory management system by integrating AR technology and equipping workers with AR mobile devices so that the data and information flow can be updated in real-time, eradicating errors and inaccurate stocktaking.

In the order picking process, augmented reality devices and handsfree AR devices can support workers in the picking and shipping of items, assisting the worker in the navigation of the warehouse, recognising and picking the correct item for shipping, barcode reading and automatically updating the management system or ERP system that is currently in place. This increase worker efficiency, reduce errors, reduces training times of staff through the continuous guidance and support, and optimises the warehouse management.

***Industrial example 1**:* https://www.cerekon.com/connecting-things-iot

Cerekon: Their picking solutions offer real-time object recognition, barcode reading, indoor navigation, and integration with Warehouse Management (WMS) Systems and Enterprise Resource Planning (ERP) Systems.

Training

For SMEs who wish to train their staff in new work process steps and educating their in-house apprentices, virtual reality technology offers a range of solutions to reduce training times and cut training costs. VR technology can replicate a company shop floor, machinery or any worker/operator situation, and allow the

[17] Adobe Image stock

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user to experience, to learn and practice without restriction of time constraints and without interrupting the manufacturing process and production. VR training sessions can be created and customised for every kind of work situation and can recreate any kind of work process scenario.

Virtual Reality Training often makes use of Head mounted display (HMD) hardware such as the Oculus Quest or HTC Vive. To become familiar with these technologies please refer to the Hardware section of the VAM Realities State of the Art Report. Standard training scenarios are available for download on to these HMDS, however a customised scenario will often require the expertise of VR service providers unless the company has the necessary expertise in-house.

For workers/operators who have completed VR training, and are still becoming familiar with new work processes on the job, the introduction of augmented reality technology can assist them on conducting their work correctly, through support and guidance software, that communicates to them directly which steps they need to take in the new work process, by superimposing instructions through visual and audio in AR headsets and other AR technologies

***Testimonial**:* Machinery producer Belgium

"We use the ARKITE Human Interface Mate in 3 different workstations. This technology projects instructions, buttons, instruction video's, colour marks, text, etc. on the table, on the product, on inventory bins, on tools. It supports the operator in a welding station and in a human assembly station where it shows the operator the sequence of the bolts and nuts he has to fasten. If the operator tries to fix the wrong bolt or nut his tool doesn't work!"[18]

The training opportunities are not just restricted to new work processes, the same is also true for the training of workers and employees in Health and Safety aspects and in dealing with Hazardous scenario. Health and safety procedures are a requirement of all companies these days, and accurate training is a key element of preparation for emergency situations. VR training allows workers and employees to train and prepare for these situations realistically and allows the employee to practice for such scenarios. VR training can replicate company facilities but importantly can safely create emergency situations and allow employees to practice without the limitation of time and cost. This is particularly true in high-risk hazardous emergency situations such as fires and chemical spills, but also particularly beneficial for staff safety training in hazardous working conditions or situations, that require a high level or risk mitigation and safety procedures, such as working with chemically hazardous or flammable substances, or working at heights for example.

[18] Paraphrased from the VAM REALITIES European Survey Report (Interview 1 from Partner KULeuven)

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***Industrial example 3**:* www.ludusglobal.com

Ludus is a platform for safety training through Virtual Reality courses.

Figure 31: Example of Virtual reality industrial training[19]

The capabilities of Augmented reality in supporting repair work and remote maintenance are highly beneficial to SMEs in manufacturing, as a solution to be used when support the company's own clients but also for the company itself as a user of industrial machinery produced by other manufacturers. This is particularly relevant for workers/operators who deal with maintenance issues on a regular basis. Using technology such as AR headsets and smart glasses workers/operators can be guided by teams of expert maintenance technicians using audio and visual instruction from remote locations to diagnose and solve maintenance problems of production machinery.

19 https://i.ytimg.com/vi/e5EEpvRedso/maxresdefault.jpg, 12.04.2021

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Industrial example 4: https://pointr.com/

POINTR is a remote collaboration solution for professionals powered by Augmented Reality

Figure 32: PointR use of AR for remote maintenace
Source: https://pointr.com/

Testimonial *:* Finnish company making use of AR remote maintenance:

"When a machine breaks down somewhere, it's usually out of work for days or weeks. Travel costs come out of their own pocket; it then takes a lot of time to locate the fault. So, if you could check it initially via AR and try to check the main issues before you start to read some in-depth electrical manual, that could speed up things a lot. The client's own maintenance crews are usually very proficient but subcontractors not necessarily so much. The maintenance engineers are on the phone 24/7 and there are several thousand machines all over the world. Language barriers (German, Italian…) also create problems when you try to guide people remotely on the phone."[20]

[20] Paraphrased from the VAM REALITIES European Survey Report (Interview 2 from Partner Tampere University)

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Figure 33: Example of Remote maintenance using Augmented reality[21]

Routings for starting and implementation

With the opportunities there are of course many challenges that have to be foreseen to the best of our ability. Experiences from implementation of this technology in the business operations context have highlighted some of the following challenges.

The success rate of the technology is often dependent on the ability and willingness of the worker/operator to embrace the technology. For SMEs with experience in adopting new technologies, this is less so of a challenge, and much of today's workforce are tech-savy with the widespread individual acceptance of mobile devices and smart phones.

The current operations systems and infrastructure of the SME also can be challenging in the adoption of both VR/AR technology. The majority of VR/AR technology is a newly developed technology and its compatibility with older operating systems is understandably limited and dependent on each induvial solution of software.

Further challenges also include the setting and environment that VR/AR is exposed to in a business operations setting. The majority of this technology is user-friendly and comfortably build, and not particularly robust. For example, it is recommended to not leave many of the

21 https://xrgo.io/wp-content/uploads/microsoft_remote_assist_0.jpg, 12.04.2021

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VR/AR devices in direct sunlight for extended periods, and most devices are intended for an indoor environment. However, there are specific devices, such as AR glasses that are robust and purpose built for industrial settings, for example the already mentioned AR Iris tick Smart Glasses (that enable hand-free remote assistance, step by step workflow guidance are at the same time also certified as industrial safety glasses.[22]

One also has to consider the issue of worker/operator endurance and sustained usage when considering VR/AR technology. For many workers the introduction of a technology such as a ergonomic AR smart glasses, is a enabling tool, and can be used extensively in their daily work routine. Sustained usage of VR technology can be slightly more challenging, as the effects of nausea and dizziness can follow extensive usage as well as the comfort complaints of wearing a VR headset that typically weigh approx. 500- 600 grams[23]. The endurance levels vary from user to user, however typically users of VR headsets can comfortably endure 90 to 120 minutes of uninterrupted usage before requesting a respite and the guidance of the Oculus Quest device recommends taking breaks from usage every 30 minutes[24]. (Further in-depth analysis available in the VAMR*S State of the art report)

Tools and Solutions

The amount of AR and VR solutions available to business operations is as diverse as the number of challenges faced by companies in their business operations. Each situation requires a suitable solution. Generally speaking, in a business operations environment when dealing with workers and operators, a virtual reality solution that involves a mobile wireless HMD is probable most appropriate, which leads itself to in-company training scenarios. A virtual HMD such as the Oculus Quest 2 ranges in price from €500 to €600[25] per headset. In terms AR technology, a streamlined user-friendly solution such as AR smart glasses are desirable considering the extended usage by workers/operators. A solution such as the Vuzix AR glasses ranges from approx. €450 to €2500 [26]depending on capability. However, each situation requires a certain solution with relevant VR/AR software and hardware. An unbiased overview of current VR and AR hardware is available in the VAMR*S State of the Art report. This document also provides an overview of available VR and AR software as well as relevant and

22 https://iristick.com/, 12.04.2021
23 https://www.threesixtycameras.com/vr-headset-comparison-table/,12.4.2021
24 *Health and Safety Warnings,* Oculus Quest 2 Operating instructions, (https://www.oculus.com/legal/health-and-safety- warnings/), 12.04.2021
25 Source: Online price check May, 2021
26 Source: Online price check May, 2021

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compatible software with VR and AR technology, including price, pros and cons and independent review.

Uses Cases

The following set of use cases outline how SME manufacturing companies in Europe have successfully integrated VR and AR technology into their business processes and the benefits to the respective companies

Use Case i) An Italian company employing less than 100 people building customized automatic systems for the assembly of different products, specifically commissioned by customers from several industries such as automotive, cosmetics and furniture. The company developed a VR solution for training purposes in design and in training. This VR solution is used to train the company's machinery operators as well as their clients machinery operators in a completely virtual environment, without having the necessity of stopping the machineries while they are operationally functioning.

"With VR we want to give the operator the opportunity to be trained in an offline environment on the management of the machine, the system and its maintenance."

Simultaneously the company has employed an AR solution for ordinary and extraordinary repair and maintenance services. This AR solution allows the interaction between the operator and the machinery. With this AR solution, machinery operators can see the virtual representation of specific mechanical objects in their mobile device (e.g., a tablet), the operating parameters and real-time monitoring, as well as the procedures to be launched when they detect coded faults. If a new fault is detected and not already present in the knowledge base, the operator is supported by the AR solution in interacting and disassembling the part of the machinery that requires an intervention.[27]

[27] Paraphrased from the VAM REALITIES European Survey Report (Interview 6 from Partner CNR/STIIMA)

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Figure 34: Example of warehouse management using Augmented reality[28]

Use Case ii) A Belgian supply company employing 160 people has adopted an Augmented Reality solution to restructure its Order picking process. The company uses an AR application to support the order picking process. Since some of them were not so keen to wear AR glasses, company management choose an AR solution that is available on two alternative AR systems: **Vuzix AR glasses** or else a mobile device such as a tablet or a smartphone. The employed system only uses codes, numbers and signs and works as much as possible independently from any specific language. For example, the order drop point positions in the warehouse are digitally represented by a number, not by the name of the customer. This is an important consideration, as the company employees' personnel coming from 13 different countries. The AR solution has helped implement measures to reduce human errors and as a result the company is now working at a service level of more than 99%.

The company reports that although during the implementation of the AR solution the company undertook a thorough analysis of the product flow and the daily attention to all preparatory actions, the payback period of this AR implementation was shorter than 12 months. The company sighted improvements in both order picking speed and eradicating picking errors.

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28 https://media-exp1.licdn.com/dms/image/C4E12AQESukpVL48zvw/article-cover_image-shrink_720_1280/0/1559741919694?e=1622678400&v=beta&t=l2n057yQ0KHcPF6ATmbn5okoFvx48NMfLN0ubr4--DA, 12.04.2021

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"From the beginning I wanted a very simple solution, easy to use, language independent and preventing most human errors. This is especially important when new employees start working in our company. The system reduces the length of their run-in period. For the worker undertaking the order picking, the system has a very limited number of buttons to push. This is necessary to attain high working efficiency"[29]

For further examples and illustrative uses cases please refer to the VAMR*S European Survey as well as the extensive list of use cases in the VAMR*S State of the art report.

Figure 35: Example of Warehouse management using Augmented Reality[30]

Conclusion

For SMEs involved in the manufacturing sector there are an ever-increasing amount of solution focused on dealing with the challenges faced in business operations. However often SMEs face difficulty in how to become familiar with these technologies and making informed decisions on which technologies are appropriate for their company, their work process and which is compatible with their existing infrastructure. The VAM Realities project has taken significant steps to ease the journey for SMEs by developing a range of tools to address these challenges. The VAM Realities State of the art report gives a overview of VR/AR technology in general, and also gives an unbiased and independent review of VR and AR hardware and software on the current market, suitable for SMEs in manufacturing. The Report also highlights a range of use cases to guide and inspire SMEs in how this technology can assisting the manufacturing processes. Possible to rephrase this

[29] Paraphrased from the VAM REALITIES European Survey Report (Interview 4 from Partner KULeuven)
[30] Adobe stock

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part? It is in almost every chapter now. THE VAM Realities project has also made available via it the VAM Realities project website a directory of listed VR/AR experts located across Europe that can guide SMEs on taking decisions related to VR/AR investments and provide support.

However, SMEs need appropriate access to this technology in order to experience hands-on its potential, and the VAM Realities project has arranged the XR SME Coaching programme. This programme invites SMEs involved in manufacturing to undergoing a coaching programme directly with the project partners of the VAM Realities project that will give hands-on experience to SME staff and in-depth coaching in the latest VR/AR technology, give access to current hardware and in cooperation together implement and develop appropriate VR/AR solutions for participating SMEs. Please refer to Chapter 10 of this handbook for full details of the VAM Realities XR SME Coaching programme.

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How Virtual and Augmented Realities can support and enhance Marketing and Sales in manufacturing SMEs

Chapter 06

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6. How Virtual, Augmented and Mixed Realities can support and enhance Marketing and Sales in manufacturing SMEs

Author: Kari Peltola, Wakeone (Finland)

Introduction

In sales and marketing, creating a connection is critical. SME manufacturing companies are looking for better ways to enhance their communication with their prospects and customers. Virtual reality (VR), augmented reality (AR) and mixed reality (MR) technologies (XR) are emerging as the new frontier of sales and marketing.

Figure 36: Virtual reality enables emotional experiences
Source: Unsplash

For an SME manufacturing company, these technologies provide major opportunities. In this chapter, some of the opportunities and challenges are described. Moreover, some tools and case examples are presented to provide context and an effective starting point.

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Opportunities

Making time and space irrelevant

Sales and marketing are fundamentally about communication. The value of a product or service has to be communicated clearly and in a compelling manner to the potential customer. Research suggests that companies are already seeing AR and VR to excite and create 'wow effects' for customers.[31]

Some of the biggest advantages of XR technologies come at play when the product or service has some of the following qualities:

- Physically large
- Complex
- Highly customized
- Large number of products or variations.

Large products

Size is not an issue in the virtual world. Whether the machine is 30 cm, 3 meters or 3 kilometers in length, it will fit the virtual world. The physical machine might be impossible to move to the customer's site for a presentation. Virtual versions can be taken practically anywhere using AR and VR, making it possible to bring them into the actual context whether it is a factory, a building site or a marketing event.

Complex product or service

It might be difficult to fully understand the inner workings of a glass tempering machine or a network station and, especially, the difference between a high-end product and a cheap copy. If the actual machine or process is not available, complete visual representation will enable better communication.

[31] Jalo, H.; Pirkkalainen, H.; Torro, O. (2021), S.17.

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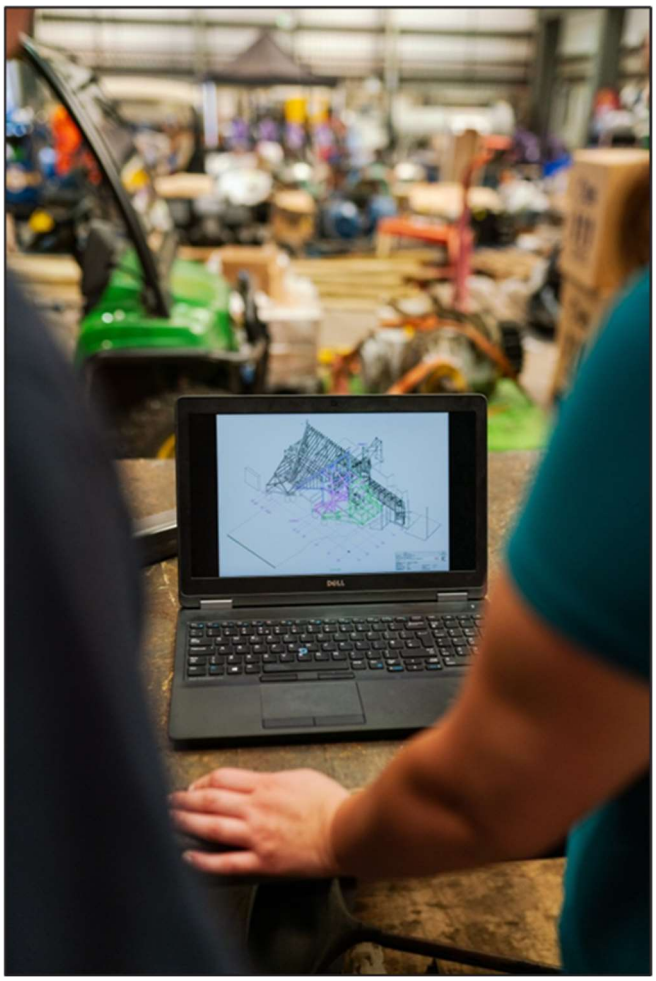

Figure 37: Complex product design
Source: Unsplash

Customized products

When companies produce things that are customized for a specific customer there are no examples to showcase. All products are shipped immediately to the customers when they are ready. With XR, you can show all the variants and all the possibilities that might be relevant for the customer.

Large number or products or variants

Company's product line might consist of many different products or product variants. Bringing all of them to a physical industry fair or marketing event setting might not be possible but presenting them in a virtual format is.

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Defying distance

Year 2020 showed that travelling cannot be taken for granted in the future. Still, sales and marketing efforts cannot stop even if there are no sales visits or fairs. Digital tools must be used effectively to close the sale, even if there would be no way to physically meet. XR technologies will provide the next level of virtual meetings and a more profound digital impact compared to normal videoconferencing platforms.

Emotional impact

XR is something exciting and new. It is a whole new, more natural, paradigm for our daily communication. Across the XR domain there are really interesting possibilities to create experiences that challenge the current media formats and will enable differentiation and better brand recognition for those companies adopting them.

Implementation and Challenges

Implementing XR technologies to support SME manufacturing companies in their sales and marketing activities can be started from lightweight approach and taken into deeply integrated systems, depending on the calculated ROI for the use case. It is good to note that, even if XR is becoming more mature, it is still not an everyday technology for everybody in every situation. Limitations need to be taken into account in order to capture ROI.

Implementation quick steps

- ✓ Best way for a manufacturing SME without previous experience in XR technology is to contact an expert (a specialized market party or a HEI) that can provide insight on the available tools and hardware in relation to their business case. For a company that has some technical expertise and resources to do internal experiments, an increasing number of lightweight solutions exist. You can find some notable ones in the State of Art report produced by the VAM Realities project.[32]
- ✓ Try out hardware and experiences yourself to understand the medium. VR and AR cannot be fully explained in words, they must be actually experienced to fully understand both the power and the shortcomings of the technology.
- ✓ Experiment with different approaches to match your needs to the correct solution.

[32] Tepljakov, A.; Kose, A.; Petlenkov, E. (2021) Virtual and Augmented Reality: State of the Art Technology Report, Estonia: VAM Realities

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In addition, the VAM Realities project also provides a European-wide network of experts to help companies with their questions and challenges. You can look it up at www.vam-realities.eu.

Expected ROI

Expected return on investment (ROI) varies a lot depending on how the technology is used. One area where it is possible to get high ROI fast is using XR to showcase large products on a fair setting. Combined logistical and fair stand cost is usually from € 3.000 upwards. When using virtual machines instead of real ones you can recover the cost of the investment in just one fair participation.

As an example, Ricoh's portfolio of production presses and platforms including complementing software services can cost up to $2 million. To ship these products to demo sites around the world cost over $150 000 per printer, per event. Yearly, Ricoh's participates from six to ten tradeshows. Customers really want to dive deep with these products and Ricoh's marketing team decided that it would be a no-brainer to create a virtual experience to showcase the products better for the customers in many more situations.[33]

Content

As in any other marketing and sales medium, content creation is a crucial part of the success. Content needs to be designed and created. In XR domain, that is usually a job for a professional. Either the company hires somebody with the content creation skills or purchases services from a supplier specialized in this area.

[33] Augmented Reality for Enterprise Alliance (2021) AR and VR deliver ROI via efficiencies and cost reductions

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Figure 38: Mobile AR hardware is very accessible today
Source: Unsplash

Hardware

Level of usability and quality varies a lot between specific XR technologies. In order to produce quality results, hardware needs to be matched with the specific use case. For example, if you need to present a detailed UI solution that requires showing readable text in the digital screens, some VR headset types just cannot be used because of the resolution.

Process integration and peopleware

Most of the current XR hardware and applications require at least moderate IT skills. Some simple applications can be operated in a plug-and-play fashion but moving into anything advanced requires some training and capabilities to work with new technology. Thus, an SME starting to take advantage of this technology should gather sufficient understanding in-house to be able to fully take advantage of this technology.

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Helpful Tools and Solutions

Multitude of tools and solutions already exist. VAMR*s State-of-art report lists many of them in more detail but as a starting point a manufacturing SME could start by looking into the following categories.[34]

Content will be crucially important in using XR technologies in sales and marketing. The VAMR*s Network is a good starting point if the company looks to proceed with the help of a specialized content creator. If the company has their own resources, the following tools, applications, and channels are great for starting.

Game engines and asset stores

Most of XR experiences and applications are made using either Unity or Unreal. These are game engines that enable both (almost) drag-and-drop style content creation and more complex things that might require actual coding. Unity asset store is a great place to start finding resources for the 3D development.

Handheld 360 cameras

One of the easiest ways of creating VR content is to purchase a handheld 360 camera and shoot some footage from e.g. a factory. At the time of writing this paper, some decent options include for example Insta360 and GoPro Max. Various applications exist for showing these photos and videos.

[34] Tepljakov, A.; Kose, A.; Petlenkov, E. (2021) Virtual and Augmented Reality: State of the Art Technology Report, Estonia: VAM Realities

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Figure 39: 360 cameras are getting smaller and better
Source: Unsplash

Application stores

Depending on the use case and technology, it is possible that some applications already exist. For VR it is good to check out Oculus store, for mobile AR Apple store and for advanced mixed reality things Microsoft's channels.

Use Cases

Companies have utilized XR in their sales and marketing efforts for quite some time now. Here are some examples of bespoke solutions for more effective marketing and sales in various types of use cases.

Virtual showroom for huge machines – Wakeone

It has been impossible to transport anything but the smallest press brakes in Aliko's selection for presentations at fairs, for instance. Products have been presented to clients in their premises with the help of videos and brochures, but during the autumn of 2018, the company began using an AR application that utilises Wakeone's XR Showroom's extended reality capabilities and enables every nook and cranny of the machine to be viewed on a tablet, even from the inside (https://xrshowroom.fi/en/customers/aliko-oy-ltd/).

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Figure 40: XR Showroom provides VR and AR modes to showcase products
Source: Wakeone

AR in brochures for brand engagement – Arilyn

Mobile AR presents a scalable immersive solution for marketing and sales use cases. With hundreds of millions of devices supporting the technology, it is already mainstream. One great example is made by an AR focused consultancy Arilyn, for a Finnish leading outdoor equipment manufacturing company Lapp set. They offer solutions for playgrounds, outdoor sports, and park furniture.

Lapp set had multiple product categories and tailored services so a modern tool for presenting the possibilities was needed. They already had 3D models of their playground products so there was a nice base to utilize the technology. These assets were transformed into AR and added to the catalog (https://blog.arilyn.com/lappset-invites-mankind-outdoors-with-ar).

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Figure 41: Lappset AR solution
Source: Arilyn

Visual CPQ enabling smoother sales – Vividworks

No more dragging textiles around to customers who won't get an idea of the final look from just a tiny piece of fabric anyway. From now on, Lindström salespeople will have the entire product range at their fingertips – and with just a few clicks are able to show the entire selection on the customer's own premises (https://vividworks.com/customer-stories/lindstrom/)

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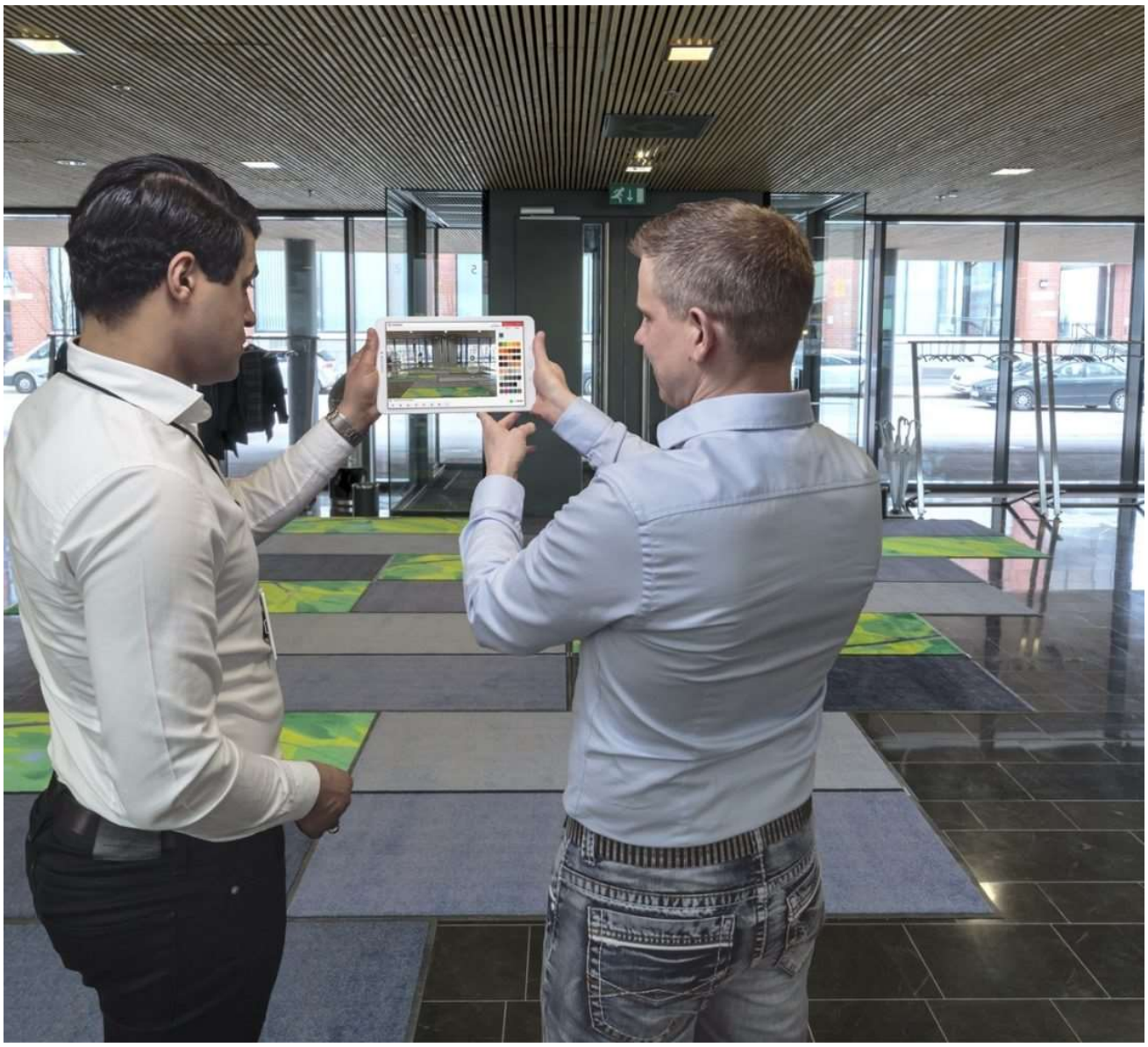

Figure 42: Lindström AR solution.
Source: Vividworks

Conclusion

VR and AR technologies are the next big frontier for marketing. Customers crave for a deeper digital experience and this is more important than ever because of current situation and future trends greatly affecting business travel.

For manufacturing SMEs these technologies offer great possibilities, especially because they're well suited to present things that are big, complex or don't exist yet.

It is good to find a development partner who understands the strengths and caveats of the state-of-art technology and can navigate the company into a successful adoption and great ROI. Iterative approach and a curious mind will make the journey enjoyable and exciting. It is time to start now!

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REALITIES

How Virtual and Augmented Realities can support and enhance collaboration

Chapter 07

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7. How Virtual and Augmented Realities can support and enhance collaboration

Authors: Henri Jalo, Osku Torro, Henri Pirkkalainen, Tampere University (Finland)

Introduction

Until very recently, SMEs have mostly relied on traditional forms of collaboration. These include for instance physical meetings where all relevant stakeholders gather in to discuss the matter at hand, such as a new product design, and long email chains where more technical matters are often discussed. SMEs have been transitioning towards using more advanced digital tools in collaboration, but they have been acknowledged to be lagging behind larger companies[35]. The COVID-19 pandemic of 2020 sent many SMEs scrambling when everyone was suddenly forced to collaborate remotely with digital tools. However, it was soon acknowledged that many of these solutions could not effectively replace face-to-face interactions. This likely led to a drop in competitiveness in SMEs in comparison to other companies which were more ready for fully digital remote work with advanced novel technologies such as AR and VR (collectively known as Extended Reality, XR) which offer higher levels of immersion. It is therefore essential for SMEs to understand how they could collaborate more efficiently with XR and why they should start using them.

Improving collaboration in SMEs is also crucial because SMEs often sell their products worldwide which means that designers and technicians have often had to travel great distances to design meetings or to install devices and fix problems. Moreover, communicating about complex technical issues with a multifaceted group of stakeholders is key to their operations. However, current remote collaboration tools (e.g., videoconferencing) have been found to be inefficient in maintaining task-related focus, innovation, creativity, and social relations, which might cause a decline in productivity in many organizations[36]. There is therefore a demand for more intuitive and immersive collaborative tools with a higher degree of “remote presence”. AR and VR have huge potential in this regard.

XR collaboration is also expected to become more effective as large technology companies, such as Microsoft, Apple and Facebook, have started developing enterprise-oriented XR

35 OECD (2021). The Digital Transformation of SMEs. OECD Studies on SMEs and Entrepreneurship, OECD Publishing, Paris.

36 Torro, O., Jalo, H. & Pirkkalainen, H. (2021). Six Reasons Why Virtual Reality is a Game-Changing Computing and Communication Platform for Organizations, *Communications of the ACM*.

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solutions[37]. Even though it is likely that we will still use many forms of traditional collaboration methods in the future, many AR and VR solutions have already proven their value in productivity gains and time-savings. Demand will therefore be there both internally from employees and externally from customers to include these as critical parts of business processes in the future. This chapter explores how AR and VR technologies could be used in SMEs to enhance their collaborative processes.

Opportunities

The collaboration capabilities of both AR and VR have developed quickly in the last few years. For example, it is now possible for multiple users to participate in a VR session from all over the world via avatars with user-friendly stand-alone VR devices. The ability to copy different real-life social cues into VR has also increased, and it is likely that we will soon have close to fully photorealistic avatars in VR which include accurate gaze and other important non-verbal cues[38]. This type of remote collaboration can be much more engaging than the video calls we've become used to (or tired of) because VR also allows you to move and communicate in the virtual space as you might in a real social situation. VR's spatial 3D setting also allows you to examine and interact with the digital content in an intuitive fashion. However, VR also makes it possible to transform social collaboration by tweaking the avatars and other features of VR. For example, changing the size of avatars or their anonymity can change the dynamics of a social situation significantly.

37 Langston, J. (2021). "You can actually feel like you're in the same place": Microsoft Mesh powers shared experiences in mixed reality. https://news.microsoft.com/innovation-stories/microsoft-mesh/

38 UploadVR (2019). Facebook VR Research: Photorealistic Face Tracked Avatars. Youtube. https://www.youtube.com/watch?v=86-tHA8F-zU

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Figure 43: Examining a VR scene with an avatar
Photo credit: Dean Calma/flickr.com*, licensed under* CC BY 2.0

Having relevant digital content in the XR space is of course key to collaboration. Importing content into AR and VR has been a challenge earlier as it has often required cumbersome and time-consuming file format transformations and model optimizations. However, in the newest solutions (e.g., Autodesk VRED and BIM360) it is often possible to natively view content in AR or VR within minutes. These kinds of fast workflows enable quick meetings and iterations on content, whatever it may be. New integrative platforms such as Nvidia Omniverse[39] also enable live collaboration in AR or VR with different popular design tools at the same time, which holds huge promise for SMEs who often collaborate with a diverse cast of companies. Combining all of their different software solutions into a common collaboration platform can save time and make collaboration more convenient as users do not have to jump between different software or worry about losing information or details with file format transformations.

Including end-users into the design process with AR or VR also becomes much easier and engaging with these kinds of collaborative methods. The end-users are also able to give more accurate and useful feedback because of the more realistic and intuitive perception that AR and VR provide. With AR, digital models and annotations can now be anchored realistically in real environments which makes it possible to examine the content with a group in the real context. For example, a new manufacturing machine can be placed in its intended location digitally with a tablet to check how it fits into the current setup. The scale of new designs and products can also be understood more easily with these technologies. More importantly, a

[39] Nvidia (2021). Developing on Omniverse. https://developer.nvidia.com/nvidia-omniverse-platform

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single identification of a major error using these methods can often pay for the initial investments into AR or VR.

Figure 44: Remote AR collaboration support with a tablet
Photo credit: Zapp2Photo/Shutterstock.com

The potential for reducing unnecessary travel with remote XR collaboration is also immense. This can give the companies a significant competitive advantage because the costs and time saved in reduced travel can be used to either make the company's products cheaper or be invested in other endeavors. Expert knowledge can be available remotely everywhere, both for design and support activities. For instance, instead of having a maintenance expert fly to the other side of the world to fix a machine that's holding up the entire production line, the expert can get an instant view of the situation with a remote AR solution and guide the local personnel in resolving the problem with intuitive AR annotations and drawings. The time saved in diagnosing and solving design or technical problems remotely can also lead to higher productivity and a better customer experience.

SMEs which operate globally will see the most benefits from AR and VR collaboration because earlier they have often had to travel on-site to fix an issue that could've been solved quite easily with remote AR assistance for example. Technical designs can also be displayed to stakeholders more visually and intuitively which can reduce mistakes in the design and better ensure that the product matches their needs. Evidence for massive returns on investment

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(ROI) have also been reported. For example, Bell managed to complete their new concept helicopter design ten times faster after they transferred their collaborative design processes into VR[40]. Kia also managed to shorten their global design reviews from several days to mere hours with Varjo's VR/XR glasses[41]. Time savings of 25% or more are also often reported after AR has been adopted in collaborative manufacturing processes[42].

How should SMEs go about using AR and VR in collaboration?

So how should SMEs begin approaching using these technologies in collaboration? In essence, we see there are three main avenues:

- Testing XR with product vendors or at industry events
- Experimenting with the technologies in university cooperation
- Testing them independently.

Figure 45: Testing VR at an industry event
Photo credit: Stephan Sorkin/Unsplash

40 HTC VIVE (2018). Bell Brings Revolutionary FCX-001 to Market 10x Faster With HTC VIVE. Youtube. https://www.youtube.com/watch?v=9rF2NBEHOow

41 Varjo (2021). Case Kia: Driving the Future with XR Collaboration in Car Design. https://varjo.com/case-kia-autodesk-vred-driving-the-future-with-xr-collaboration-in-car-design/

42 Porter, M. E. & Heppelmann, J. E. (2017). Why every organization needs an augmented reality strategy. Harvard Business Review, 2017 November-December Issue.

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When it comes to AR and VR software, pretty much every collaborative enterprise XR software has a free trial period available which makes it quick and easy to test them and see if they could be useful. The challenge is really with the hardware. Overall, the range and affordability of AR and VR hardware has improved significantly, enabling them to be used more widely than ever before. For AR, these can roughly be divided into smartphone and tablet-based AR and head-mounted displays (HMDs) such as the Microsoft HoloLens or Vuzix smart glasses. Smartphones and tablets are of course ubiquitous and testing remote AR collaboration and other use cases with them is very quick and easy. Their interface and interaction methods are also familiar to everyone so the barriers for testing are very low overall. AR HMDs on the other hand can be quite expensive so it is smarter to test their collaborative use with vendors or universities.

Stand-alone VR devices on the other hand could be purchased for test use due to their low cost, however, more advanced VR headsets (such as Varjo XR-3) should be tested before purchase to evaluate whether they are necessary for the intended collaborative activities. Many people are also still quite unfamiliar with AR and VR so it might be easier to test their collaborative capabilities in a facilitated setting (i.e., with vendors or universities). Higher education institutions (HEIs) should therefore acquire some basic AR and VR hardware and software as well to enable internal and external stakeholders to test these technologies. This would also allow them to be used in various university and online courses, as well as in conjunction with self-learning materials which can help in developing the necessary XR skills for students.

To make XR collaboration a reality, the technological install-base (i.e., how widespread AR and VR devices are in the organization and with its stakeholders) needs to be at a sufficient level to enable collaboration and for the network effects to start taking place. This will also increase incentives for adopting these solutions for others. Smartphone-based AR can be considered to be the most mature in this regard, but VR is also getting there as cheap and powerful standalone headsets have become popular (e.g., Oculus Quest 2 has already sold more than all previous Oculus headsets combined[43]).

[43] Bloomberg (2021). Facebook Reality Labs VP: VR Will Transform Global Work. Bloomberg. https://www.bloomberg.com/news/videos/2021-03-29/facebook-reality-labs-vp-vr-will-transform-global-work-video

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Tools and Solutions

What are some examples of XR collaboration solutions that SMEs should try then? When it comes to remote AR collaboration, there are really numerous apps available, for example DeltaCygniLabs Pointr, Teamviewer Pilot, Microsoft Dynamics 365 Remote Assist, Vuforia Chalk and Scope AR. For collaborative AR visualizations, Microsoft Dynamics 365 Product Visualize and Augment offer intriguing possibilities. VAM Realities project partner 3DQR also offers an advanced AR visualization solution that can be used for various collaborative activities.

For VR, SMEs might want to check out some basic social multi-user VR software first to acquaint themselves with its potential. Some possibilities include AltspaceVR and enterprise-focused collaboration apps like Glue and Spatial which have more advanced functionalities. VR also has many specialized collaborative software for different industries. In the construction industry for instance, Resolve and IrisVR have become popular recently. In the manufacturing context specifically, Mindesk VR allows live collaborative editing of CAD files in VR with support for the most popular CAD software. It is also important to note that many industrial design software already boast native VR visualization and collaboration capabilities (e.g., Autodesk VRED), so SMEs should first check out if their current design software could already be used for AR or VR.

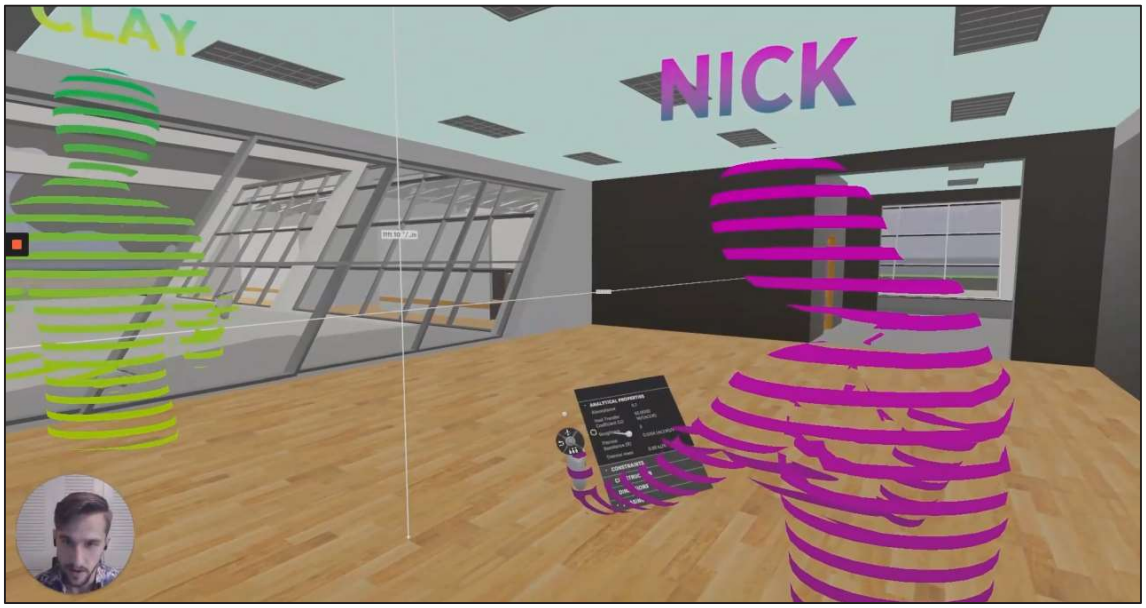

Figure 46: Viewing and discussing digital designs in VR is easier than ever before
Photo credit: CoBot Studio, licensed under CC BY-NC-ND 2.0

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As an overall collaborative suite including both AR and VR, Microsoft's Mesh seeks to combine multiple tools and devices in an immersive collaborative platform[44]. The aforementioned Nvidia Omniverse (currently in beta) also offers an integrative collaboration platform for both AR and VR. VAM Realities project partner Wake one's XR Showroom also allows you to view and discuss your digital content either in VR or AR depending on the situation.

What types of collaboration can be enhanced with AR and VR?

Overall, AR and VR can be used in many different collaborations use cases. Design collaboration in VR can help in combining designs together with different experts faster, in identifying errors in the design, and in collecting more useful stakeholder feedback. The benefits for designing in VR can be immense. For example, Bugatti managed to reduce their car design time by 40% with VR when compared to traditional methods[45], which already likely paid off their initial investments into VR many times over. Off-the-shelf VR solutions can also be implemented very quickly, however, customizing the solution will naturally take more time. It is also possible to hold more informal virtual meetings in VR, but in the SME context, collaboration around relevant digital content is likely to yield the most benefits. It is also important to emphasize that collaboration in VR doesn't always have to be done in real-time because the virtual space can also act as a persistent platform where users can leave notes and comments on the digital content for their colleagues to check on later. Moreover, these changes and other interactions can also be gamified to increase engagement.

44 Microsoft (2021). Introducing Microsoft Mesh. Youtube: https://www.youtube.com/watch?v=Jd2GK0qDtRg

45 Glon, R. (2020). Out with the clay, in with the VR: Bugatti's design studio is all digital - Bugatti's head of design told us why virtual reality is better. Autoblog. https://www.autoblog.com/2020/02/20/bugatti-design-studio-virtual-reality-vr

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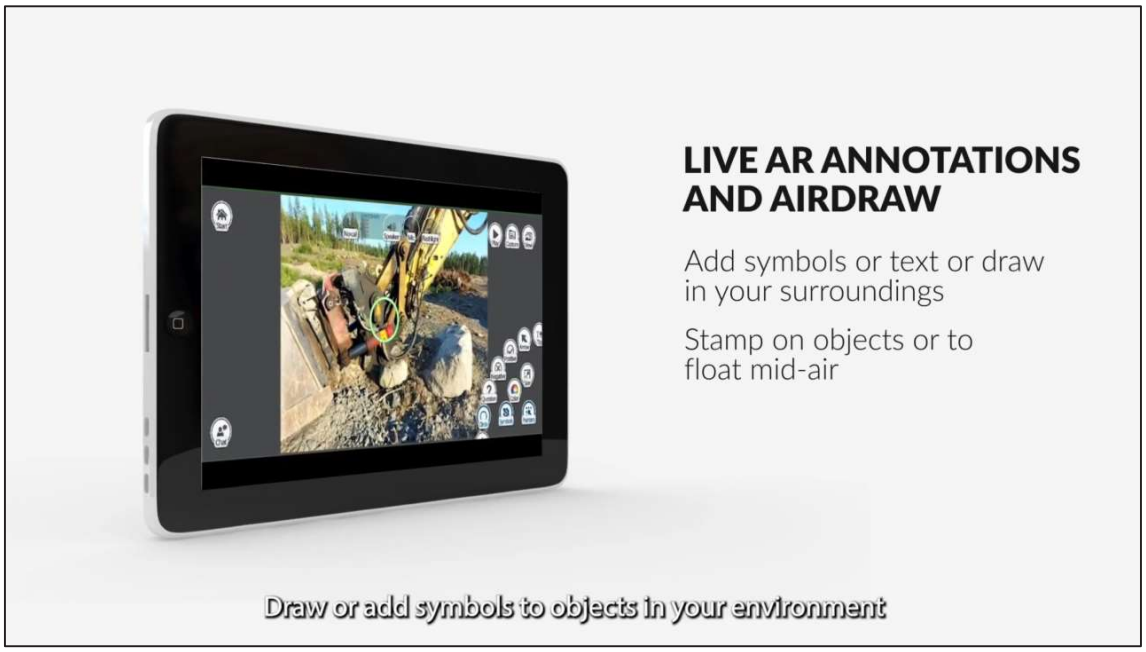

Figure 47: Collaborative design review in VR
Photo credit: Gorodenkoff/Shutterstock.com

AR can be used especially in remote collaboration support, which is likely the most low-threshold XR solution that most SMEs should explore. The barriers for adopting such a solution are low because companies can simply install the remote support app into their existing smartphones and replace traditional phone calls with this approach. Visualizing digital models with AR can also be helpful for on-site visualizations (e.g., visualizing a building in its intended building location) or displaying products in general (e.g., the IKEA Place AR app) to communicate about them efficiently to a group of stakeholders. Displaying digital information in relation to existing physical assets with AR can also be considered to be a form of asynchronous collaboration. For example, an expert's repair instructions could be attached to a machine to be accessed via a QR code and visualized to other employees in the actual context with AR.

Conclusion

The COVID-19 pandemic of 2020 might have been a turning point for many SMEs which created the impetus to adopt more effective remote collaboration solutions. Many companies found tremendous benefits from XR solutions during this time and gained a competitive advantage by using them to increase the effectiveness of remote collaboration. Even though at first these solutions might have been used out of necessity as face-to-face collaboration became impossible, it is likely that future demand for them will be created by good XR collaboration experiences and accrued benefits. However, many SMEs are still unsure about how they should proceed with their own digital transformation when it comes to XR. In this regard, HEIs can also play an important role in helping SMEs achieve their goals in transforming their collaborative

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practices by joint research projects with SMEs, offering XR infrastructure for testing and brainstorming, and by facilitating student-SME workshops and exercises on how XR could be implemented in business.

Finally, here are a few key questions for you to think about if you are interested in using XR in collaboration:

- What are the most critical communication bottlenecks in your organization?
- How could XR be used to solve these bottlenecks?
- Who are the key personnel in your organization who could benefit from the use of XR in collaboration?
- What are the key digital assets in your organization that could be used in XR?
- What collaborative workflows could be transferred into XR environments?

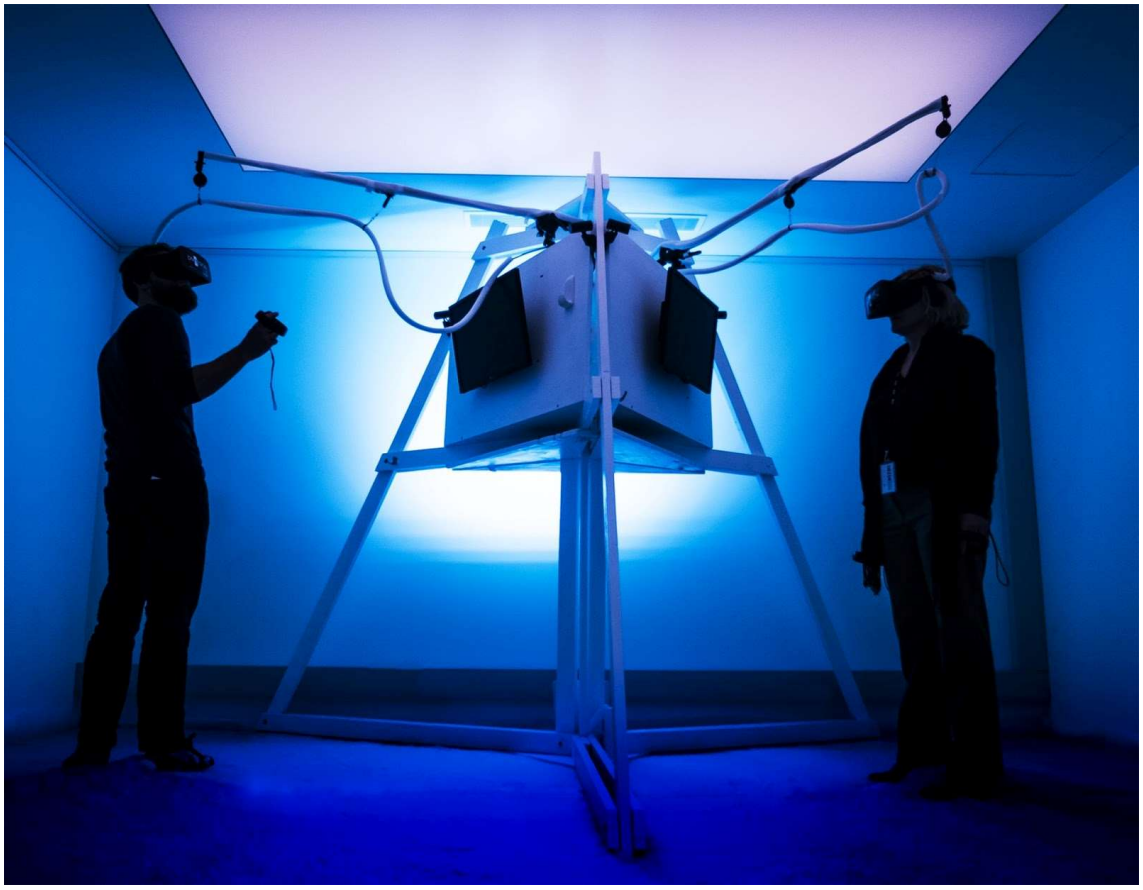

Figure 48: Collaborating in VR
(Photo credit: Stella Jacob / Unsplash)

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REALITIES

Legal & Regulatory challenges regarding VR, AR, and MR applications

Chapter 08

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8. Legal & Regulatory challenges regarding VR, AR, and MR applications

Authors: Leandros Savvides and Marios Zittis, CARDET (Cyprus)

Introduction

The adoption of VR, AR, and MR (in short: XR) technologies has reached a tipping point in recent years, mainly because of the development of more accessible, easy-to-use, and affordable hardware to a large user base. European XR companies - and around them an ecosystem of new start-ups - are growing and contributing to an expanding base of users. The rapid expansion of these modern technologies has created new legal and regulatory challenges that concern the developers, the users, and other affected or involved parties, which will be discussed in this chapter.

Due to its diverse nature, the regulatory framework around XR technologies needs to take into account the varieties of offerings that are usually processed. At high-level quality, there are broadly three main areas of engagement: **content**, **service**, and **technology**. However, the most important topics that SMEs need to take into account are issues concerning safety, data privacy, and intellectual property rights.

While commercial XR products (i.e., XR games) are being developed, sold directly to the consumer market by XR content companies, and are easily consumed by users, SMEs that aim to utilise such technologies for their own work are facing multiple barriers. These potential problems and barriers might prove capital-intensive to solve and can involve legal advice on activity, finding the right talent to develop UX (User Experience) and UI (User Interface) design, expert talent recruitment, etc.

SMEs focus on the infrastructural technology that provides the basis of value to the industry, including headset manufacturers, modelling solutions, analytics platforms, etc. According to Whiskard et al. (2018), the key challenge to adoption of Mixed Reality technologies for operation purposes, is the cost associated with high amounts of data, relatively expensive equipment, as well as the low familiarity of employees to such technologies and in need of training. Scale is important, as “some visualization tools suited to larger facilities may be too expensive, require too much expert knowledge and require technical prerequisites that are not available within

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small facilities" (Ibid. p. 2)[46] Kwon and Son (2018)[47] also mention differences in business thinking by SMEs, "For large companies and/or established companies, promising technologies are selected in consideration of technology traits, market traits, government policy, and suitability to their companies. In determining "suitability to their companies," small and medium-sized enterprises take the reliability of stable profit rather than long-term investment and large profits most importantly compared with large companies."

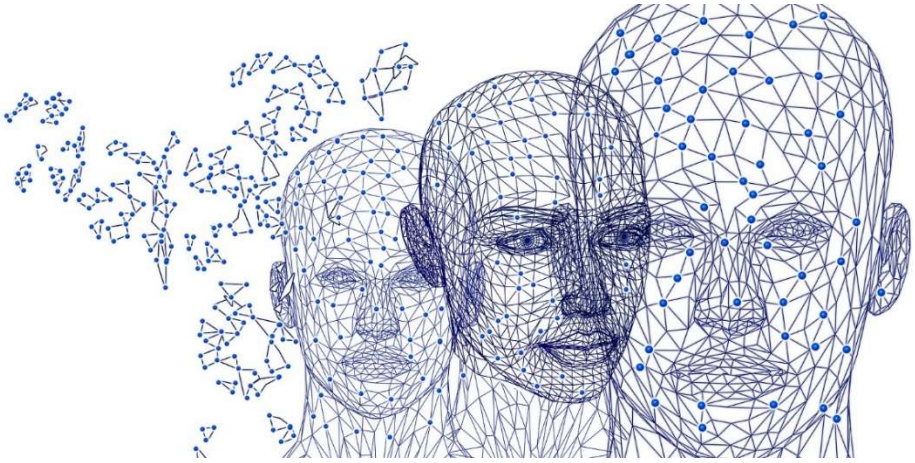

Figure 49: Meeting on virtual spaces
(Photo credit: Pixabay)

[46] Whiskard, H., Jones, D., Voller, S., Snider, C., Gopsill, J., & Hicks, B. (2018, July). Mixed Reality tools as an enabler for improving Operation and Maintenance in Small and Medium Enterprises. In *IFIP International Conference on Product Lifecycle Management* (pp. 3-14). Springer, Cham.

[47] Kwon, Y. I., & Son, J. K. (2018). A Case Study on the Promising Product Selection Indicators for Small and Medium-Sized Enterprises (SMEs). *Journal of Open Innovation: Technology, Market, and Complexity*, *4*(4), 56.

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Ownership and IPR

As the application of XR technologies expands, more data is needed for the collection and recording of the immediate environment of individuals. This creates confusion on a variety of issues, such as who owns the data, how it is stored and used and who has access to such information. Therefore, issues of ownership and IPR (Intellectual Property Regime) are important landscapes to be developed.

At the same time, as the technology matures, more significant needs and opportunities for regulation and standardisation emerge. Standardisation[48] allows a wide network of actors to identify opportunities, estimate costs, and understand the reliability of utilising such technologies. In this respect, in 2017, IEEE (the world's largest technical professional organisation) announced P2048™, a Virtual Reality (VR) and Augmented Reality (AR) standards project in advance of participation at Augmented World Expo. This was part of identifying and developing a framework for understanding the new unfolding VR/AR landscape.

As such, it is evident that technical associations are attempting to disentangle the various issues arising from the development of XR technologies. The landscape for such environments is new in respect to the ambiguity of ownership - and therefore responsibility - against the law. There seems to be a difference regarding the context of illegal activities between US and EU firms. There have been a number of thought experiments regarding visceral behaviour within VR environments, for example, assaulting within a virtual game[49] , which increasingly challenges the boundaries between what is real and what is not and who has responsibility for acts which happen in the application.

In the US, at the moment, a virtual reality provider "*may be subject to contract and property law for the actual exchange of goods and is subject to consumer protection laws*." However, the General Data Protection Regulation (GDPR) takes another route as it regards the EU; it requires owners of platforms and developers of such virtual environments to implement privacy and comply with GDPR by design.

According to Daniel Koburger (2019), in the US, "many of the legal issues that concern the virtual world and its users today - such as virtual ownership of digital goods and freedom of speech on virtual platforms - are viewed by the legislature in favour of the controllers of virtual

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48 See for example https://www.etsi.org/deliver/etsi_gr/ARF/001_099/001/01.01.01_60/gr_arf001v010101p.pdf

49 Belamire, J. (2018). My First Virtual Reality Groping. Medium. https://medium.com/athena-talks/my-first-virtual-reality-sexual-assault-2330410b62ee#.swe1c0pgr

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platforms"[50]. As a result, many of the legal issues that are raised within such environments fall on the hands of platform holders and developers of such VR worlds "*through end-user license agreements (EULAs) and terms of service (TOS) with few legal boundaries*"[51]. The reason for this profound freedom for developers and owners of such virtual environments is granted on the basis that such environments are the development of private companies, and theoretically, technologically, and legally, they are "*merely facilitating communication and information*"[52]. If SMEs invest in such technologies, there has to be a more transparent framework on what constitutes liability and how standardisation can give continuity to operations.

Figure 50: The importance of data in XR
*Photo credit: ThisIsEngineering/*Pexels

According to a Euro found working paper[53], there have been an increasing number of patents on virtual reality since 2014, despite the technology being around since at least 1998. The acquisition of Oculus Rift (a headset manufacturer) by Facebook is seen as a tipping point for the widespread commercialisation of the technology. A similar trend has been seen with regards to AR technologies since 2010.

A number of Trademark issues may arise because of grey areas in which the virtual or augmented worlds posit. For example, one issue that may be of confusion is the difficulty on the part of the IP owner to trademark not only in terms of the physical/tangible product but also the

50 Koburger, D. B. The Game Changers: "Viscerality" and Public Space.
51 Ibid.
52 Ibid.
53 Eurofound. (2019). *Virtual and augmented reality: Implications of game-changing technologies in the services sector in Europe*. https://euagenda.eu/upload/publications/untitled-262817-ea.pdf

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content generated intangible virtual representation that emerges[54]. Another issue is the extent to which evidence of damages via IP in platforms can be proven.

One example given is the use of the Pokémon Go, an AR mobile application which sends users to particular places to collect Pokémon's (fictional creatures from the game). To which extent can a company claim that it does not want its logo and brand to be associated with the app, and in turn, to which extent can the app claim that it adds value to companies via the use of the game? Much of such new environments are not standardised and regulated, thus so far there are speculations on what needs licencing. A characteristic question of the unstandardised state of the technology is posed in Immersive UK and Digital Catapult programme's (a UK manufacturing programme) report[55] on the growing importance of VR and AR: "An avatar wearing branded clothes in a VR world or racing branded motor cars in a VR game – does it need owners' consent?"[56] Much of such questions are based on scenario cases, to be used to build in the standardisation process. This matter is extensively discussed by the academia and the legal community and is expected to be legally regulated in the future.

In terms of licensing, SMEs can use VR platforms that are based on open software[57]. As licensing can be a limiting factor for adoption, using open-source software can be of significant help. OpenSim and Second Life are both open and can - under technical conditions and the collaboration of professional designers and programmers - offer significant help in overcoming issues of licensing (Liagkou and Stylios 2019). Who owns the virtual space is certainly an issue of importance for SMEs. It is important to have a clear understanding on who is able to invoke access as a third-party. This might involve increased costs resulting in disentivising adoption by SMEs. One solution given that could potentially resolve confusion in terms of ownership is when "a VR/AR platform provider should include in its terms of use provisions which specify ownership and usage rights for IP rights arising from activities within the VR or AR environment" (Ibid p. 74)

Patent filing seems to be no different than any other technology. Perhaps differences concerning user interfaces and motion-tracking technologies are new, but all other basic elements are the same: that inventions "*must be new, involving an inventive step and suitable for industrial*

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54 Dentons. (2019). Virtual reality and trademark/patent law. https://www.dentons.com/en/insights/articles/2019/october/3/virtual-reality-and-trademark-patent-law

55 Immerse UK & Digital Catapult. (2019). The immersive economy in the UK 2019. https://www.immerseuk.org/wp-content/uploads/2019/11/The-Immersive-Economy-in-the-UK-Report-2019.pdf

56 See more on this here, https://www.pwc.co.uk/intelligent-digital/vr/growing-vr-ar-companies-in-the-uk.pdf

57 Calvo et al. (2017). Towards a methodology to build virtual reality manufacturing systems based on free open software technologies. International Journal on Interactive Design and Manufacturing (IJIDeM), 11(3), 569-580.

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application"[58]. There are no specific laws on VR and AR environments, so the same IP laws apply. It is evident that SMEs will have difficulty protecting their own interests via patenting their own work, as it requires time and capital and confusing legislation regarding the new cases arising from such environments.

Safety

According to an Immerse UK and Digital Catapult report[59], in the UK (as well as in the EU), at this moment the field lacks standardisation and hence may lack health and safety standards. However, as with previous technologies - such as Bluetooth for wireless, 4G/5G for mobile communications, and MPEG for video - protocols and standardisation procedures are expected to emerge in the following years. The report notes, that "some of these existing and developing standards for traditional technologies will also be highly relevant to components of VR/AR platforms, and VR/AR specific standards are also being developed by bodies such as:

- IEEE, which is conducting Project 2048.5 to develop a standard for VR and AR: Environment Safety.
- 3GPP (the mobile standards organisation), which conducted a workshop in December 2017 reviewing VR standardisation issues. Global Virtual Reality Association (GVRA) – supported by Acer, Google, HTC Vive, Oculus, Samsung, Sony, and StarVR Corp.
- OpenXR, which aims to provide an open standard for applications to run across different VR systems and devices without having to be ported from one to another.
- The Virtual Reality Standards Board, which recommends standards for commercial VR facilities" (Catapult digital 2018, p.60)[60].

As evident above, in recent years there has been a gradual recognition of XR environments in regulatory frameworks. An example of such a case is the use of VR to simulate flight conditions by Varjo and VRM Switzerland, the first virtual reality simulator officially qualified by the European Union Aviation Safety Agency (EASA). According to the developers, such a VR environment "enables flight schools and helicopter companies to use the latest technology to

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58 Dentons. (2019). Virtual reality and trademark/patent law. https://www.dentons.com/en/insights/articles/2019/october/3/virtual-reality-and-trademark-patent-law

59 Immerse UK & Digital Catapult. (2019). The immersive economy in the UK 2019. https://www.immerseuk.org/wp- content/uploads/2019/11/The-Immersive-Economy-in-the-UK-Report-2019.pdf

60 Digital Catapult & PWC. Growing VR/AR companies in the UK. https://www.pwc.co.uk/intelligent-digital/vr/growing-vr-ar-companies-in-the-uk.pdf

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increase flight safety, to offer more cost-effective training solutions, and to train in a more environmentally friendly way, at any time."[61]

Understandably, as the technology was going through a phase of infancy, safety was not a top priority but rather the ability of the technology to make VR and MR environments a reality. This is evident in De Guzman, Thilakarathna, and Seneviratne (2020 p. 2) work in which they reveal "most of the work on MR for the past two decades have been focused on delivering the necessary technology to make MR a possibility. As the necessary technology is starting to mature, MR devices, like any other technology, will become more available and affordable. Consequently, the proliferation of these devices may entail security and privacy implications which may not yet be known." [62] Previous works support this claim as there has been a number of issues addressed, such as enabling technologies, interfacing, visualisation, performance alignment interaction, mobility (Azuma et al. 2001; Rabbi and Ullah 2013; Chatzopoulos et al. 2017) as well as head mounted display technologies (Kress and Starner 2013) but none "have focused onto the fundamental issues of security and privacy in AR or MR".

As such, a number of considerations are taken into account via situations that arise from MR/VR environments to accommodate concerns related to work, responsibilities within the applications, insurance, and the possibility of cyber-attacks. De Guzman, Thilakarathna, and Seneviratne (2020) suggested that there are varieties and categories of threats which users and companies need to take into consideration. Some threats have to deal with input of information, for example, taking user-sensitive information via the immediate environment of the user (emails, chat logs etc., even information that is not intended to be shared but can reveal information about the user) which can compromise even the safety of the user. Other categories of threats include data protection (especially as it regards to who controls the user-generated data), output protection (who has access to which application is of paramount importance to reliability of data), user interaction protection and device protection. Roesner et al. (2014) suggested that in order to solve complex senor system problems which may arise in the future, one possibility is to leverage "AR technologies to detect privacy or security conditions of which the user should be alerted. For example, rather than relying on compliant cameras to shield users from unwanted recording, a system could alert users when it detects camera lenses pointed at them, using (for instance) computer vision to detect the glint of light reflecting off a

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61 See more in the announcement "Varjo and VRM Switzerland make history with the first virtual reality simulator officially qualified by European Union aviation Safety Agency EASA, available here https://varjo.com/company-news/varjo-and-vrm-switzerland-make-history-with-the-first-virtual-reality-simulator-officially-qualified-by-european-union-aviation-safety-agency-easa/

62 De Guzman, J.A., Thilakarathna, K. and Seneviratne, A., 2019. Security and privacy approaches in mixed reality: A literature survey. ACM Computing Surveys (CSUR), 52(6), pp. 1-37.

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lens. It could also detect some forms of eavesdropping, e.g., a laser microphone pointed at a window."

The issue of safety and security is complex, only now entering the consideration of law and policy makers. Any endeavour to provide a comprehensive framework should require careful testing before implementation.

Figure 51: Sharing experiences in VR
Photo credit: Lucrezia Carnelos/Unsplash

Data Privacy and Security

Many SMEs do not necessarily face an "awareness" problem regarding the EU General Data Protection Regulation (Regulation 2016/679/EU – "GDPR"), it is rather a problem of "capacity" for them. According to a report on the SME experience of the GDPR, a large number of SMEs may be lacking the resources to be able to compete and be compliant at the same time[63].

According to expert advice by law firm Dentons, some of the issues faced by SMEs regarding the GDPR and local data protection regulations are still unaddressed to unlock barriers. One of the issues raised is the processing of biometric data where VR technologies collect body-tracking data (fingerprints, voiceprints, hand and face geometry, electrical muscle activity,

63 STARII. (2019). Report on the SME experience of the GDPR. https://www.trilateralresearch.com/wp-content/uploads/2020/01/STAR-II-D2.2-SMEs-experience-with-the-GDPR-v1.0-.pdf

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heart rate, skin response, eye movement detection, head position, etc.). The use of such data falls under the 4(14) of the GDPR, "*personal data resulting from specific technical processing relating to the physical, physiological or behavioural characteristics of a natural person, which allow or confirm the unique identification of that natural person, such as facial images or dactyloscopy data*", which means there must be an explicit consent unless used for some very limited purposes[64]. The issue of consent is central for the use of such virtual environments, but there is a concern whether "*data subjects have "real choice" to refuse the processing and whether it is possible to draw the line between necessary and unnecessary data.*" In other words, users might not be able to distinguish between qualitative differences in VR and AR environments, what data is necessary to access and what is not. Such biometric data can be used in business in many useful ways but there is a lack of comprehensive framework guarding data privacy.

Another kind of data which needs consideration in terms of data privacy is non-verbal data. In the legal framework the responsibility and concerns of such sensitive data is yet to be acknowledged. Developing algorithms for example, based on individual body language or user responses in events within the application may "have value outside of VR because it is fairly simple, even using older technology, to capture and categorise body movements in the real-world using computer vision"[65]. In this sense, hours of personal use within VR systems will provide the training data for algorithms that pair body language with subsequent behavioural outcomes, but the value in estimating outcomes could extend to the real world. The science fiction notion of determining future behaviour ¬– whether about what people buy, if they are ill, whom they want to date, or even if they might commit a crime ¬– becomes a possibility" (Bailenson, 2018). But not only in terms of behavioural outcomes for consumer choices, the use of 360-degree VR video (Miller et al., 2020) for example raises concerns over the power of authorities and the extent of the power of law enforcement, especially in areas which suffer of systemic discrimination. Amnesty international researcher Matt Mahmoudi (2021) has raised such concerns suggesting that "facial recognition risks being weaponised by law enforcement against marginalised communities around the world. From New Delhi to New York, this invasive technology turns our identities against us and undermines human rights."[66]

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64 Anselmi, N., Olivi, G., & Miele, C. O. (2019). *Virtual reality: top data protection issues to consider*. JDSUPRA. https://www.jdsupra.com/legalnews/virtual-reality-top-data-protection-43864/

65 Bailenson, J. N. Protecting Nonverbal Data Tracked in Virtual Reality. JAMA pediatrics. 2018; 172 (10): 905–906.

66 See here, Ban dangerous facial recognition technology that amplifies racist policing, available online https://www.amnesty.org/en/latest/news/2021/01/ban-dangerous-facial-recognition-technology-that-amplifies-racist-policing/

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As it pertains to data security, there seems to be a reliance on VR systems on third party services or applications which do not appear to implement suitable security standards. As a result, there is a concern over potential data exposure to unauthorised personnel[67]. Moreover, data security covers another problem for businesses, which is events of data loss because of a disaster such as fire, flood, or any kind of data compromising. Security should be in place to be able to ensure business continuity in order to be reliable for adoption[68]. This means, that extensive reliance on virtual data formats, without the relevant capital-intensive infrastructure to ensure the security of data, can result in not being able to perform critical operations for the firm.

67 See also ethical dilemmas addressed here: Eurofound. (2019). Virtual and augmented reality: Implications of game-changing technologies in the services sector in Europe. https://euagenda.eu/upload/publications/untitled-262817-ea.pdf and De Guzman, J. A., Thilakarathna, K., & Seneviratne, A. (2019). Security and privacy approaches in mixed reality: A literature survey. ACM Computing Surveys (CSUR), 52(6), 1-37. https://arxiv.org/pdf/1802.05797.pdf

68 See also: Hunt, C. (2018). VR and your privacy: how are these companies treating your data? know where your data's going. Windows Central website. https://www.vrheads.com/vr-and-your-privacy-how-are-these-companies-treating-your-data, 25.08.2021

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Guidelines and suggestions for SMEs

1. **Evaluate the cost-benefit analysis of XR use in production**: smaller companies think differently than large ones in adopting XR solutions. Because their competitiveness lies in their ability to increase capacity performance to distinguish themselves from competitors, they are sceptical on long term investments, especially when the economic environment is not favourable, and the standardization process is low.)[69]
2. **Are you lacking compatible software – hardware**: Make sure that the software solution you choose is compatible with the hardware device choice as well?
3. **Find the right skilled personnel**: Finding the right personnel need not to be strictly of the same industry. The gaming industry is an example of highly skilled personnel which usually is a good pool of people familiar with XR technologies and can work efficiently and confidently.
4. **Provide training to ensure familiarity with XR usability**
5. **Find the right quality software to address your needs**
6. **Make sure that the software/hardware of choice is of regulated standards**
7. **Make sure your staff and workers are aware of the possible risks and violations to their data protection (DP)** when using VR applications, and give them an opportunity to agree.
8. **Make sure your staff and workers follow all necessary safety precautions** as provided by the VR Hardware manufacturer. These precautions are provided by the hardware manufacturers, either in a written or other formats. For example:
    - **Oculus Quest safety video**: https://youtu.be/7TFWckMXCWk
    - **Oculus Quest 2 safety video**: https://www.youtube.com/watch?v=Ke4MefpmRmc
    - **Oculus Rift S safety video**: https://youtu.be/Xn6BR4X--fY
9. **Make sure your staff and workers are aware of the possible risks and violations** to their DP when using VR applications for design collaboration meetings in VR.
10. **Make sure the VR platform provider guarantees a secure connection and a closed VR room with only invited users** before sharing and uploading sensitive material such as 3D CAD drawings of company products.
11. **When Using AR technology for Remote maintenance with an external colleague**, make them aware of the DPA situation and possible risks involved.

[69] See more here, https://www.iapmei.pt/getattachment/PRODUTOS-E-SERVICOS/Industria-e-Sustentabilidade/AnalysisDrivers.pdf.aspx 25.08.2021

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Conclusion

In a technical sense, VR/AR/MR are merely environments that stimulate the senses using communication content, text audio and visuals. But on the other hand, what emerges, as a result, is much more than its technical inputs. There is a complication on the boundaries just like the early internet use was facing a few decades ago. For this matter, SMEs' use of such technologies would benefit from further regulation and definition in standardised and legal language but only insofar as the regulation eliminates the costly barriers (e.g., capital-intensive IPs).

The continuous development and application of XR technologies has created a gap in law, regarding personal data, standardisation, copyright, privacy and security. As this technological sector grows, and new challenges erupt, the need for new legislation that will regulate the matters revolving around VR, AR and MR grows. It is expected that new legal frameworks addressing these challenges will emerge soon and will furtherly develop with the expansion of the XR applications in different sectors and purposes.

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European Steel Skills Agenda: https://www.estep.eu/essa/essa-project/

SMeART: http://www.smeart.eu/ and https://vam-realities.eu/wp-content/uploads/VAM-Realities_Survey-Report.pdf, visited April 11, 2021

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CMI BLOG - Data Storage for SMEs: What you need to know. https://www.newcmi.com/blog/uk-london-it-provider-data-storage-for-smes-0

VRinSight Curriculum - Boosting Virtual Reality Learning within Higher Business Management Education https://www.vrinsight.org/

The State of Augmented Reality, Mixed Reality and Virtual Reality adoption and use in European small and medium-sized manufacturing companies in 2020

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REALITIES

Strategic and Managerial opportunities and challenges

Chapter 09

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9. Strategic and Managerial opportunities and challenges

Authors: Joseba Sainz de Baranda (Federación Vizcaína de Empresas del Metal) and Aitor Goti (Universidad de Deusto), Spain

Introduction

Sustainability of the business over time and profitability of the company are usually the most critical issues addressed by SMEs managers. Companies are facing new managerial and organizational challenges in the context of the 4th Industrial Revolution, to adopt new technologies which can achieve the desired results with minimum input and within a limited period of time. In the context of the explosion of Virtual, Augmented and Mixed (VAM) realities, the aims of this chapter are:

a) Show briefly which AR/MR/VR applications are the most useful and target-oriented for the needs of manufacturing Small and Medium Enterprises (SMEs).
b) How to deploy these technologies in a company that considers AR/MR/VR (XR) as an opportunity. As usual, the latest technology is always here to change the world, but both management and organizational challenges and re- or upskilling needs must be taken into account.

Figure 52: VR Workplace
Photo credit: www.pexels.com

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Opportunities

Strategic opportunities for industrial SMEs

The field of virtualization and immersive technologies has been considered strategic in the industrial sector, especially in Civil Engineering, Food, Oil & Gas and Machine Tools; sectors where such a technology is considered as a key reference for smart factories, a new platform for scenario testing and decision making.[62, 63, 64, 65]

Strategic opportunities for industrial SMEs derive from Smart factory adoption of VR/AR/MR as a new platform for scenario testing and decision making, combining modeling techniques such as CAX or Discrete Event Simulation to AR/MR/VR techniques.

Figure 53: VR in Manufacturing Environment,
Photo credit: www.digitalsme.eu

62 Akyazi, T.; Goti, A.; Oyarbide, A.; Alberdi, E.; Bayon, F. A Guide for the Food Industry to Meet the Future Skills Requirements Emerging with Industry 4.0.

63 Akyazi, T.; Oyarbide, A.; Goti, A.; Gaviria, J.; Bayon, F. Roadmap for the future professional skills for the Oil and Gas Industry facing Industrial Revolution 4.0. Hydrocarbon Processing 2020. November 2020, 49-51.

64 Akyazi, T.; Alvarez, I.; Alberdi, E.; Oyarbide, A.; Goti, A.; Bayon, F. Skills Needs of the Civil Engineering Sector in the European Union Countries: Current Situation and Future Trends. Applied Sciences 2020,10 (20), 7226, https://doi.org/10.3390/app10207226

65 Akyazi, T.; Goti, A.; Oyarbide, A.; Alberdi, E.; Carballedo, R.; Ibeas, R.; García-Bringas, P. Skills Requirements for the European Machine Tool Sector Emerging from Its Digitalization. Metals 2020, 10(12), 1665; https://doi.org/10.3390/met10121665

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What is more, strategic European sectorial and intra-sectorial projects such as the Steel ESSA (Industry-driven sustainable European Steel Skills Agenda and Strategy[66]) or multi-sectorial Digitalization of Small and Medium Enterprises[67] identify XR technologies as essential. It is considered important to develop a strategic plan for future adoption of these technologies. These kind of projects and initiatives offer a transnational umbrella of training entities, technological suppliers, companies, and clusters promoting the implementation of XR techniques and providing implementation support as well as opportunities for testing the newest AR/MR/VR hardware and software and gaining skills in using these technologies.

Organizational and managerial opportunities and challenges

There are numerous advantages related to XR technology that SMEs could consider:

- Less traveling, carrying out works without going to a site.
- Advanced services and training in dangerous environments.
- Show the company in detail in real time.
- Increase the efficiency and agility in the design and start-up of productive facilities.
- More security for field staff - industries are sometimes located in harsh environments which are difficult to access or in environments with a serious safety risk. XR technologies permit a safe and immersive approach.
- Predictive maintenance - technicians could be directed by a smart device to the exact location of an industrial component or process measurement in need of a maintenance check.
- Spatial sense: VR is a tool that solves the problem of spatial sense. For example, it is hard imagining proportions when looking at a 2D plan of a construction.
- Marketing – unique selling point: VR is a trend topic and attracts customers.
- Immersion: XR offers people a possibility to collect impressions and experiences at a new level and to get better insights in processes.
- Virtual testing - One strength of VR is that it gives you the possibility of trying and testing in a virtual environment, which would not be possible in real life.
- Knowledge transfer - VR gives you the possibility to communicate special knowledge to other people in a seemingly real situation.[68]

The detection of business-, organizational- or managerial opportunities for SMEs related to new technologies and new trends in management and organization, usually requires specific resources, most of the time not available or difficult to detect within the SME itself. Regional,

66 European Steel Skills Agenda: https://www.estep.eu/essa/essa-project/
67 SMeART: http://www.smeart.eu/
68 VRinSight Curriculum - Boosting Virtual Reality Learning within Higher Business Management Education https://www.vrinsight.org/

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national and EU professional organizations ecosystems (Associations, Clusters, Chambers, VET providers, public bodies, etc.) give the opportunity to SMEs to reach those resources easily.

Figure 54: Worker testing VR equipment,
Photo credit: www.unsplash.com

As a main challenge in management and organization, the executive level will need to maintain connected to the customer base and the conventional management system will change from controlling workers to active engagement, understood as a mutual transfer of knowledge between the manager and operational levels. Furthermore, while it is possible that a management hierarchy will exist, the decision process will be through the collective understanding of the shared knowledge. In general, workers will not be passive agents, but "knowledge workers" with a more active role in the organizations.[69]

Apart from the theorical business opportunities related to this technology, what usually drives the implementation of XR technologies is customers' opinions and feedback, so a common investigation and discussion to find the most value in novel XR solutions and identified use cases can be a good practice for SMEs. Another suitable approach for SMEs to know if there could be a business opportunity is investigating what competitors are up to in this field, either

[69] Davies R, C. (2017). Review of Socio-technical Considerations to Ensure Successful Implementation of Industry 4.0. Procedia Manufacturing, 11, 1288–1295.

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other SMEs or larger enterprises. The support of consultancy firms or specialized agents is vital to have a clear idea of what is happening in this respect at a sectorial level.

In this regard, there are some trending topics as data management, data storage, security and privacy that should be taken into account as well for future XR implementations (see chapter 8 of this Handbook). The point is that organizations create a lot of information and need updated systems to manage it locally or remotely. This data can be categorized into three areas:

1. Information that doesn't need to be easily available e.g., data needed for compliance reasons.
2. Information stored for backup and disaster recovery, to bring a business back from downtime or serious events.
3. Information that is easily accessible for daily computing, database and application needs.[70]

How to start: Implementation routing

Industry application areas

A Smart approach to Industry

The common factors between all the industrial application areas and even use cases regarding VR, AR and MR are basically two:

1. Enhanced communications between agents taking part in an activity.
2. Foresee what would happen in a current product, process, layout or system if some parameters are changed.

Thus, whenever a reinforcement of the communications is needed, or when it is not viable (or not cost-effective) to work with real assets, XR should be considered as a solution.

If the investment required to implement AR/MR/VR is higher than expected, but the value is still perceived, it would be smart to consider an Action Plan and a Pilot Test (see below).

[70] CMI BLOG - Data Storage for SMEs: What you need to know. https://www.newcmi.com/blog/uk-london-it-provider-data-storage-for-smes-0

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Specific applications

Taking as a basis "The State of Augmented Reality, Mixed Reality and Virtual Reality adoption and use in European small and medium-sized manufacturing companies in 2020"[71] report of the VAM Realities project, specific applications in manufacturing SMEs are:

- Design review and collaboration, to better align the needs of the customers with the efforts of the designers.
- Error detection, through simulations that check manufacturability of products or changes in process parameters.
- Remote collaboration, avoiding data format conversion delays and offering an integrative communication in eras like the current pandemic one.
- Marketing and sales, through tools like virtual product fittings (e.g., clothes fitting).
- Training, in processes where failures can have drastic consequences, or when the actual asset has reduced availability for the training.

How to: Action plan and pilot test

The following checklist can serve as a logical action plan for SMEs for taking up and integrating XR technologies in their business.

Action plan

1. Identify internal key resources to involve in the adoption of AR/MR/VR technologies
2. Familiarize your company on the possibilities and limitations of AR/MR/VR by signing up for relevant tutorials, webinars, or workshops
3. Identify critical business processes which could be transformed with AR/MR/VR and provide a high ROI for the investments. Also evaluate their impact on the company's overall business model.
4. Investigate whether your company's competitors have started using AR/MR/VR (either other SMEs or larger enterprises)
5. Discuss with your company's customers where they see most value in novel AR/MR/VR solutions and **pilot test** identified use cases
6. Examine whether your company's current software have recently introduced AR/MR/VR capabilities (e.g., streamlined BIM and CAD model exporting into AR/MR/VR) or what other available solutions could answer to the identified organizational needs
7. Identify relevant AR/MR/VR research and development projects and other sources of external support for piloting, testing, and further developing the identified solutions

[71] https://vam-realities.eu/wp-content/uploads/VAM-Realities_Survey-Report.pdf, visited April 11, 2021

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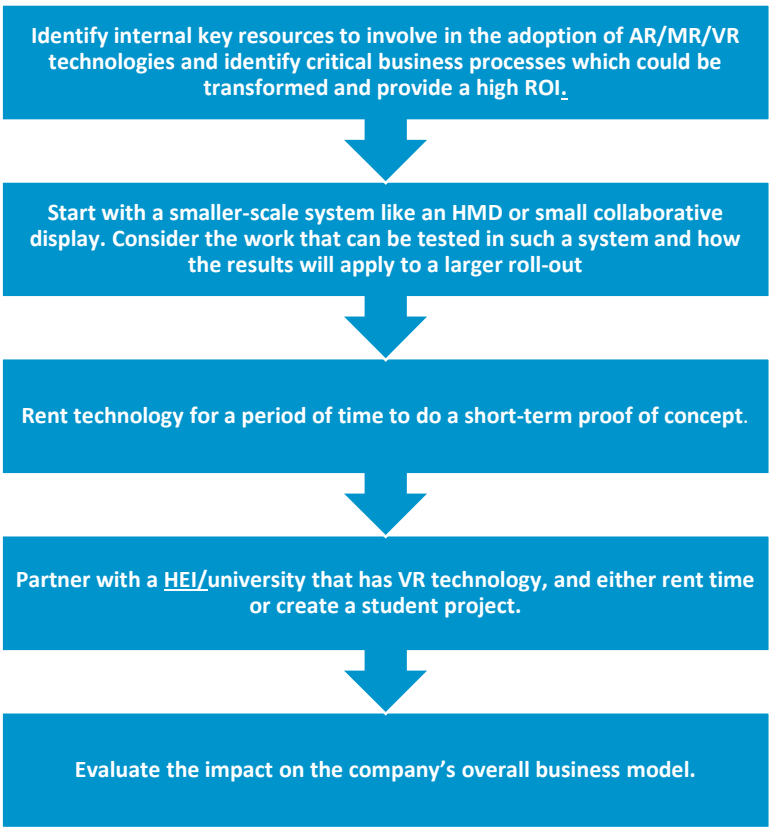
8. Identify organizations within the local innovation ecosystem (universities, research & innovation centers, industry associations, technology providers) which can provide implementation support as well as opportunities for testing the newest AR/MR/VR hardware and software and gaining skills in using these technologies
9. Formulate an AR/MR/VR strategy for future adoption and use
10. Stay up to date on the latest AR/MR/VR developments. [72]

While piloting one or more use cases, an SME could consider the following steps:

Pilot Test[73]



Developing the **return on investment (ROI) justification** for an XR investment can seem like a mountainous task, but is worth the effort. The tool ROI calculator for Augmented Reality[74], can help organizations to understand the value of enterprise AR use cases, provide data to support investment decisions and benefit from a broader view of aggregated data from across the AR ecosystem.

72 The State of Augmented Reality, Mixed Reality and Virtual Reality adoption and use in European small and medium-sized manufacturing companies in 2020

73 More info in Chapter 10 and the XR SME Coaching Program

74 ROI calculator for Augmented Reality: https://thearea.org/roi-calculator-tool-2/

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Using the ideas outlined above will provide a framework to help organizations to take the first or next step in applying this technology to their digital workflows. If a third party may be valuable to gather more information from users, a consultant could be suitable to perform interviews. While XR can add value, any investment decision should be fully informed.[75]

Skills, knowledge & competences

As part of an Action Plan for XR implementation, organizations must be aware of their internal key resources in terms of skills need and skills currently held by their workforce. This matter will be the starting point for reshaping their organizational structures and processes to fit the Action Plan in their current developing processes.

In terms of XR as one of the main Key Enable Technologies, there are several basic skills categories related to competences that organizations should take into consideration:

- **Workforce readiness** - Employees need to be ready to learn these new working systems if they are to be considered a valuable asset for the organization. Examples skills are: XR literacy, resume writing, self-presentation, time management, basic digital skills and professionalism.
- **Soft Skills** - Despite the fact that XR belongs to the tech world, personal attributes, social skills, and communication abilities that support interpersonal relationships and interactions with others are really important. Example skills are: Communication, critical thinking, creative thinking, collaboration, adaptability, initiative, leadership, social emotional learning, teamwork, self-confidence, empathy, growth mindset and cultural awareness.
- **Technical skills** - It´s obvious that a certain knowledge and capabilities to perform specialized tasks are needed to implement XR in the organization. Example skills are: Software programming, 3D-digital presentation and modeling, coding, hardware engineering, project and financial management, data acquisition functions, cloud computing-based skills, user interface (UX/UI), visualization skills, instruction/dynamic teaching, deep learning and content management skills.
- **Entrepreneurship** - Sustainability of the business over time and profitability of the company are usually related to knowledge and abilities that support success in creating and building a workplace opportunity. Example skills are: Initiative, innovation,

[75] VRinSight Curriculum - Boosting Virtual Reality Learning within Higher Business Management Education https://www.vrinsight.org/

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creativity, industriousness, resilience, ingenuity, curiosity, optimism, risk-taking, courage, business acumen and business execution.[76]

How to Conduct a Skills Gap Analysis

Here's a step-by-step process[77]:

1. **Start with your company Action Plan - Identify company goals to understand what roles will be needed in the near-term and far-term and identify internal key resources to involve in the adoption of AR/MR/VR technologies.**
2. **Identify the roles required for reaching those goals - Develop a list of roles with internal brain trust or turn to an openly available resource.**
3. **Create an inventory of skills for each role - Develop a list of the key skills needed for specific roles and priorities them.**
4. **Inventory the skills your employees have already and perform your skills-gap analysis - Find out where the organization currently stands. Numerous approaches can be implemented to assess the staff.**
5. **Perform your skills-gap analysis -** Compare the skills needed from staff against the skills they possess. The difference between those two elements is the skills gap you'll be bridging.

In order to facilitate this process, the VAM Realities project has developed a practical self-assessment tool for SMEs, called the Skills Gap Detector.

The VAM*Rs Skills Gap Detector

The *VAM*Rs Skills Gap Detector* is designed and prepared by industrial and academic XR experts, as an interactive online self-assessment on XR technology. The Skills Gap Detector consists of 20-25 selective questions, based on previously given answers. This self-assessment maps all topics related to understanding and using XR technology. After completing the assessment, SMEs can recognize the potential of XR technology in relation to their needs. The Skills Gap Detector results in an evaluation, relevant recommendations based on given answers, and an invitation to engage with the VAM*Rs coaching program that is supported by experts and partners. It is dedicated to SMEs, and it welcomes everybody in the target

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76 Preparing tomorrow's workforce for the Fourth Industrial Revolution: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/gx-preparing-tomorrow-workforce-for- 4IR.pdf

77 6 Steps to Identifying the Skills Gaps in Your Organization: https://eurekos.com/blog/6-steps-to-identifying-the-skills-gaps-in-your- organisation/

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group including technical, management, and marketing/sales representatives. The Skills Gap Detector is the best fit for individuals who have no (or no relevant) experience/knowledge in the field of XR technology. However, it is suggested that everyone with interest in this field should experience the novel Skills Gap Detector. The *VAM Realities Skills Gap Detector* is fully accessible on the *VAM Realities Online Platform* (https://vam-realities.eu/).

Use cases

General examples

The aforementioned report "The State of Augmented Reality, Mixed Reality and Virtual Reality adoption and use in European small and medium-sized manufacturing companies in 2020", explains that general examples of use cases are the following:

- On-site visualizations and marketing, as virtual and dynamic picturing of 3D-components, products, production lines, plants, warehouses, to get a buy-in of the element to be constructed or sold before assembling it physically.
- Remote support, for actions such as installation, remote maintenance or remote retrofitting; it is worth remarking that this remote support has gained widespread acceptance in the Covid era, where local technicians have retrofitted assets with the support of remote external technicians.
- Contextual information access, that eases the operations adding virtual instruction sheets to the items to be manipulated, or identifying visually an item to be tackled when we do not know where it is.

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Specific examples of business opportunities

The existing general use cases and tangible examples of XR in industry have their own transformation into specific examples, as some companies have showcased successfully. Below are some exiting XR examples which will have a great impact on how companies could face organizational and management challenges.

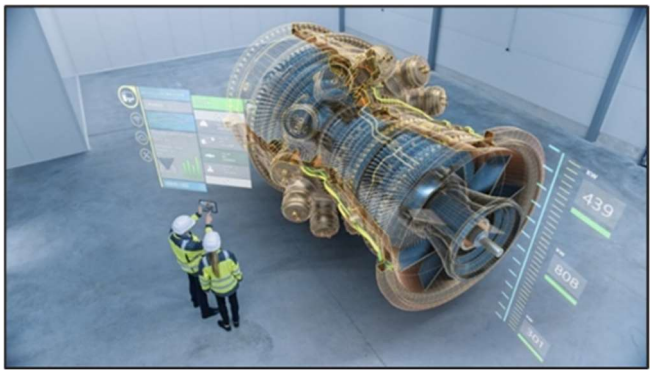

Figure 55: Aircraft engine digital twin
(Photo credit: www.sutterstock.com)

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Product Lifecycle

AR/MR/VR are impacting the various stages of a product: from product design, simulation, prototyping, manufacturing, testing, distributing, stocking to B2C marketing as well as the whole customer experience through e-commerce and end of product life management. Some examples:

AR can work interactively and intuitively on 3D-content and receive live feedback from real environments. Level up your performance by streaming entire AR applications including data-intense 3D-objects via cloud or on premises.

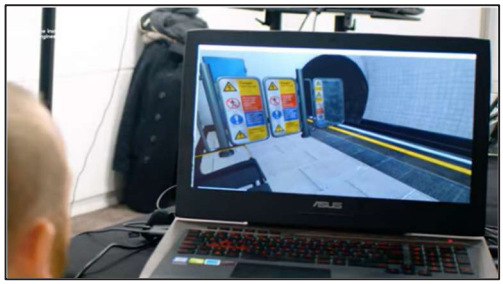
AugmentedReality Engineering: The Next Level[78]

Source: Holo-Light, YouTube

Ideas and updates in AR may easily be implemented during the product design development to support the overall aims of the project. Testing out various designs within their context, for example, is a much more agile approach instead of moving straight away to physical prototypes.

Using AR as a Product Development Tool[79]

Source:Teams Design, You Tube



A digital twin is a virtual model of a physical product, process, system, or service. The following video illustrates recent hardware and software advances and how applying virtual reality (VR), augmented reality (AR), data capture and analytics can be beneficial for business.

Digital Twin: What is it and why is it so important?[80]

Source: IET, YouTube

78 Augmented Reality Engineering: The Next Level: https://www.youtube.com/watch?v=AYd7KC0yzKw
79 Using AR as a Product Development Tool: https://www.youtube.com/watch?v=bBjIiRs7_cw
80 Digital Twin: What is it and why is it so important?: https://www.youtube.com/watch?v=1JSno8jcjwo

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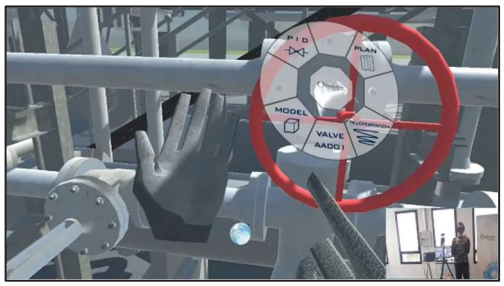
Project Management

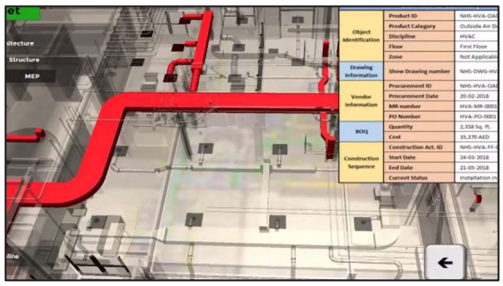
AR/MR/VR applications can support project management tasks such as planning the space for production lines or design changes during the construction phase, considering multiple factors – equipment dimensions, connections between different units, safety distances, power outlets, supply line inputs and many more. What is more, immerse technologies can be used to educate the managing team on technical requirements of the project, and how they impact the project's bottom line. Some examples:



The video illustrates how easy it is to set up an industrial layout from constructive plans using design and engineering data. The result is less risk, reduced costs, minimal start-up time, and the highest standard of safety for training purposes.

VR for Process, Energy, Naval Industry[81]

Source: ORINOX, YouTube



BIM can be used in project management to improve coordination, collaboration, and efficiencies of project teams. Augmented Reality gives the opportunity to visualize the phases of construction through an immersive platform. This can also be utilized post tender to assist with planning, giving the 3d model extended usability.

BIM Augmented Reality[82]

Source: Shine Star Services

81 VR for Process, Energy, Naval Industry: https://www.youtube.com/watch?v=Rx8zF8FRDF4

82 BIM Augmented Reality: https://www.youtube.com/watch?v=EnhOC05bacA

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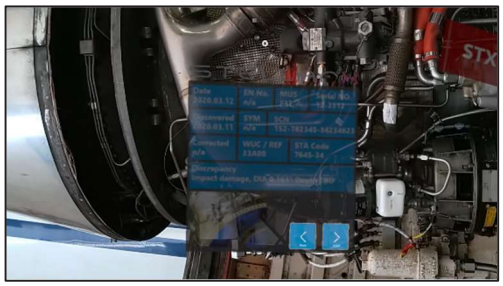
Inspection and maintenance

If we consider the manufacturing equipment inspection, we will have to admit that XR can literally reduce time and space to zero. Today, machines are becoming too complex to be inspected by the regular factory personnel. Experts can watch on site with technicians or end users of a product from all over the world. The expert can guide the user or employee live in a targeted manner to solve the problem. Both, customer, and employee remain hands-free and all relevant information can be shared quickly. Some examples:



Augmented Reality for aircraft maintenance, remote support[83]

Source: OVA,YouTube

During maintenance, planning or repair operations, some valuable time can be lost searching for technical documentation. Augmented reality through head-mounted displays can help solve those challenges, making the operators up to 250% more productive and minimizing the loss of information between inspection and repair departments.

Augmented Reality Solutions for Construction Inspection[84]

Source: SRI International, YouTube

Augmented reality solutions have the potential to transform job site operations for construction inspectors by saving time, cutting costs, and improving safety with intuitive equipment and connected intelligence.

83 Augmented Reality for aircraft maintenance, remote support: https://www.youtube.com/watch?v=O7dXn9u2WEc

84 Augmented Reality Solutions for Construction Inspection: https://www.youtube.com/watch?v=8lY4qaVvR8c

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Review of Workflows and Benchmarking

As predictive analytics have become crucial to success, XR is being used to review workflows and improve benchmarking processes. Manufacturers can see what's going on, review how workers' responsibilities could be changed, and determine if the changes would save the manufacturer money. Some examples:

Augmented reality system for production[85]

Source: CSC Concept Group

Augmented reality systems for manufacturing processes perform projecting on the production the instructions for full operator guidance. Results are automatically acquired with full data traceability. Errors are automatically detected.

Mixed Reality Solutions in process automation[86]

Source: Endress & Hauser, YouTube

XR solutions give the opportunity of receiving information about processes just by looking at the plant, and could deliver valuable insights in an intuitive way, getting the right information at the right time

85 Augmented reality system for production: https://www.youtube.com/watch?v=0m67O1Em7dY
86 Mixed Reality Solutions in process automation: https://www.youtube.com/watch?v=Hi-z4WKBOHQ

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Training

Maintaining compliance and visibility through training protocols are another area where AR/MR/VR is improving the manufacturing process. Workers can be trained in a digital environment, allowing for proactive training of what-if scenarios, which will reduce incidents, injuries, and delays in production. Some examples:

Using the original CAD drawings, students can wear virtual reality goggles to explore and disassemble a virtual aircraft mockup with an instructor before working on the actual aircraft

How Virtual Reality Tools Train Dassault Falcon Aircraft Mechanics[87]

Source: Aviation International News

Augmented reality software on headsets. Workers perform the maintenance procedure for replacing a dynamic mixer on an insulated glass sealing machine.

Manufacturing Equipment Training with Augmented Reality[88]

Source: Taqtile, YouTube

87 How Virtual Reality Tools Train Dassault Falcon Aircraft Mechanics: https://www.youtube.com/watch?v=Yb4-ASQX1AQ, 21.08.2021

88 Manufacturing Equipment Training With Augmented Reality: https://www.youtube.com/watch?v=G1xNd_n1QyE, 21.08.2021

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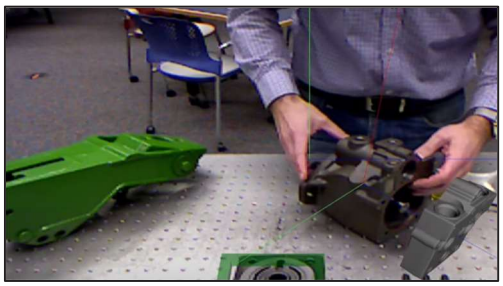
Quality Assurance and Risk Management

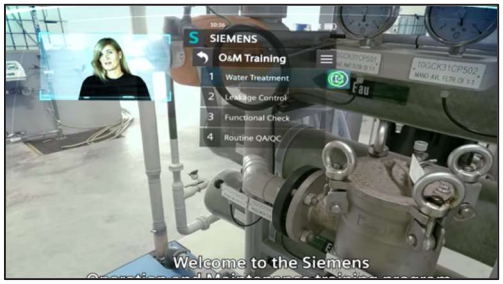
Products may not always be correctly manufactured, and risks will always be present. However, XR in manufacturing is being used to conduct a more comprehensive QA checks and manage risk by keeping all parties accountable. For example, QA applications of virtual reality may include periodic reviews of products as they're being created. Some examples:



Augmented reality for assembly assistance.

AR assembly demo[89]

Source: Rafael Radkowski



How augmented reality can support operation and maintenance in the energy business.

More than Reality[90]

Source: Siemens, YouTube

89 AR assembly demo: https://www.youtube.com/watch?v=VTBYPyWVEsE, 21.08.2021

90 More than Reality: https://www.youtube.com/watch?v=9aPo6-imjTs, 21.08.2021

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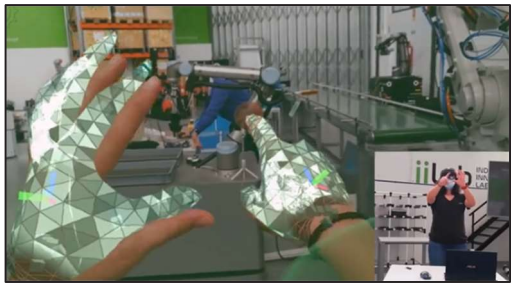
Control of Robotics

As manufacturers move towards a more efficient supply chain, the use of VR/AR/MR will increase. Virtual reality is reducing costs and helping manufacturers visualize products faster than ever before. For manufacturers like Ford, the applications of virtual reality in manufacturing are key towards growth in the 21st century, and all manufacturers should be actively working to embrace virtual reality today. Some examples:



Demonsration using Augmented Reality[91]

Source: INESC-TEC Robotics, YouTube

Programming by demonstration, using Augmented Reality.

Augmented reality with ABB Robotics[92]

Source: ABB Robotika, YouTube

Mixed reality blends holograms - 3D digital content -into your physical world. Virtual reality immerses you in a simulated world. Augmented reality overlays digital information on top of your real world. By understanding your environment, mixed reality enables holograms to look and sound like they're part of your world.

[91] Demonsration using Augmented Reality: https://www.youtube.com/watch?v=joV-4uArWDw, 21.08.2021

[92] Augmented reality with ABB Robotics: https://www.youtube.com/watch?v=Q0vpxe8mLZY, 21.08.2021

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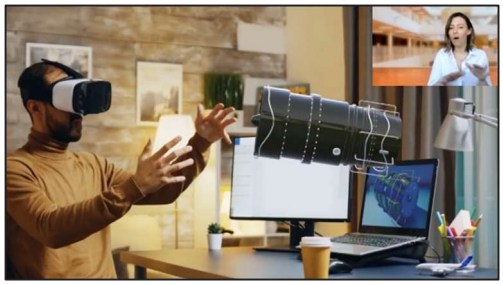
Sales strategies

Companies are looking for technologies to attract buyers, improve their time at dealerships and form a stronger emotional attachment to a product they helped create. Some examples of XR sales strategies:



Commercial design for industrial augmented reality

[ARC Commercial Design for Industrial Augmented Reality](#)[93]

Source: Mälardalens högskola, YouTube

Virtual experience of electric production process from molten metal to inspection. Implement infographic and computer graphics to improve intuitive understanding of each production stage.

[VR Plant](#)[94]

Source: HyundaiWorldwide, YouTube

93 ARC Commercial Design for Industrial Augmented Reality: https://www.youtube.com/watch?v=OfNwtgkhMS8, 21.08.2021

94 VR Plant: https://www.youtube.com/watch?v=6a97u3tkFQo8, 21.08.2021

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Conclusion

New technology is constantly changing the business environment, but management and organizational elements, as well as re- and upskilling requirements of knowledge, abilities, and competences, must be considered for an appropriate implementation of AR/MR/VR technology. If so, SMEs can obtain some of the core benefits that leading companies are getting now.

Implementation of AR/MR/VR technologies in a company is an important decision that requires a deep understanding of the current internal expertise, digitalization status of the company and market trends, so it´s really important to use the entire regional, national and EU professional organizations ecosystems (Associations, Clusters, Chambers, VET providers, public bodies, etc.) for supporting SMEs in the process.

The what-if scenario optimization of AR/MR/VR tools, along with the tools for the enhancement of both, communications among parts? and the support of operations via additional contextual information or trainings, offer a better alignment of customer expectations with the products and services a manufacturing SME offers. Considering XR action plans and piloting activities will be one of the most valuable insights to visualize the real advantage of this technology in the company.

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The State of Augmented Reality, Mixed Reality and Virtual Reality adoption and use in European small and medium-sized manufacturing companies in 2020

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VAM*Rs HEI-SME Cooperation Standards

New Skills ask for New Guidance

Chapter 10

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10.VAM*Rs HEI – SME Cooperation Standards

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Why European SMEs and HEI should look for cooperation in XR

A key aspect to be considered in the spread of AR/VR technologies adoption is the growing emphasis on cooperative relationships between SMEs and HEI (Higher Education Institutes), which play an important role respectively in economic development and innovation system (Pereira and Franco, 2021). Universities are an important source of innovation as they carry out basic research and can provide expertise specialised in companies-related disciplines or technologies as AR/VR (Battistella et al., 2017). Especially SMEs should establish strong partnerships with universities at both local and international level aimed to exchange knowledge, cover relevant competences, undertake specific R&D projects for implementing AR/VR solutions and customized methods (Zangiacomi et al., 2020).

The University-Business Cooperation is considered to be the engine towards knowledge-based societies and economies. It is specially needed in the European context, threatened by increased global competition, with ongoing economic issues and high levels of unemployment (SMeART University-Business Cooperation Model and Guidelines, 2019). Despite significant efforts by European national governments and the European Commission to increase the engagement in cooperation projects, there is still a lack of awareness of how HEI and business build mutually beneficial relationships and how related activities can interrelate (European Commission, 2018). Moreover, in European countries innovation-driven collaborations have mainly favoured large corporations (Apa et al., 2020). The HEI-business collaboration should be undertaken by matching industrial and university needs in a translational "win-win" relationship (Kurdve et al., 2020). Targeted programs, guides and tools that seek to find ways specifically for SMEs to engage more with HEI, and develop specific knowledge and skills for both academics and SMEs, are recommended (European Commission, 2018). Indeed, the engagement in collaboration with universities is shown to have a positive impact on the innovation performance of SMEs (Apa et al., 2020), and an effective adoption of innovative solutions as AR/VR technologies.

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What manufacturing SMEs have … and what they look for

SMEs are recognized as innovative and contributing to economic growth in many countries. Their business strategy is often based on flexibility, reactivity and proximity to customers and suppliers, and they can potentially exploit many opportunities of AR/VR solutions, including better planning and control processes, synchronising flows with partners and transforming their customer value proposition (Moeuf et al., 2018). Nevertheless, the introduction of new technologies and practices is always risky in SMEs: they encounter barriers as the lack of necessary resources, skills, commitment, and proper understanding of digital opportunities also due to a lack of tradition in R&D (Giotopoulos et al., 2017; Moeuf et al., 2018; Pereira and Franco, 2021). Thus, SMEs need to choose a selected group of competitive tools, practices, and actors to collaborate with, also considering their resource constraints (Battistella et al., 2017). In the field of AR/VR technologies, manufacturing SMEs are very much interested in proven, feasible and value-enhancing applications, that they can utilize or adapt for their own specific activities. SMEs have their very own dynamics and are particularly interested in how other (leading) SMEs have handled similar (technical) opportunities and challenges. These companies also need to identify the best opportunities for testing AR/VR hardware and software. University cooperation has been identified as one of the most important potentials in this regard. Due to the novel nature of XR technologies, first-hand experience with relevant use cases is essential for understanding their potential and limitations (VAM Realities Survey Report, 2021).

Opportunities and shortcomings of HEI – SME cooperation

SMEs should consider that there are major opportunities for cooperating with HEI in innovative projects - as for the adoption of XR technologies - and thus overcoming the possible shortcomings and risks. HEI as well should look for the advantages in engaging with SMEs. The figure below gives a hint in this sense (Alunurm et al., 2020, European Commission, 2018; Kurdve et al., 2020; Orazbayeva et al., 2019; Pereira and Franco, 2021; SMeART University-Business Cooperation Model and Guidelines, 2019).

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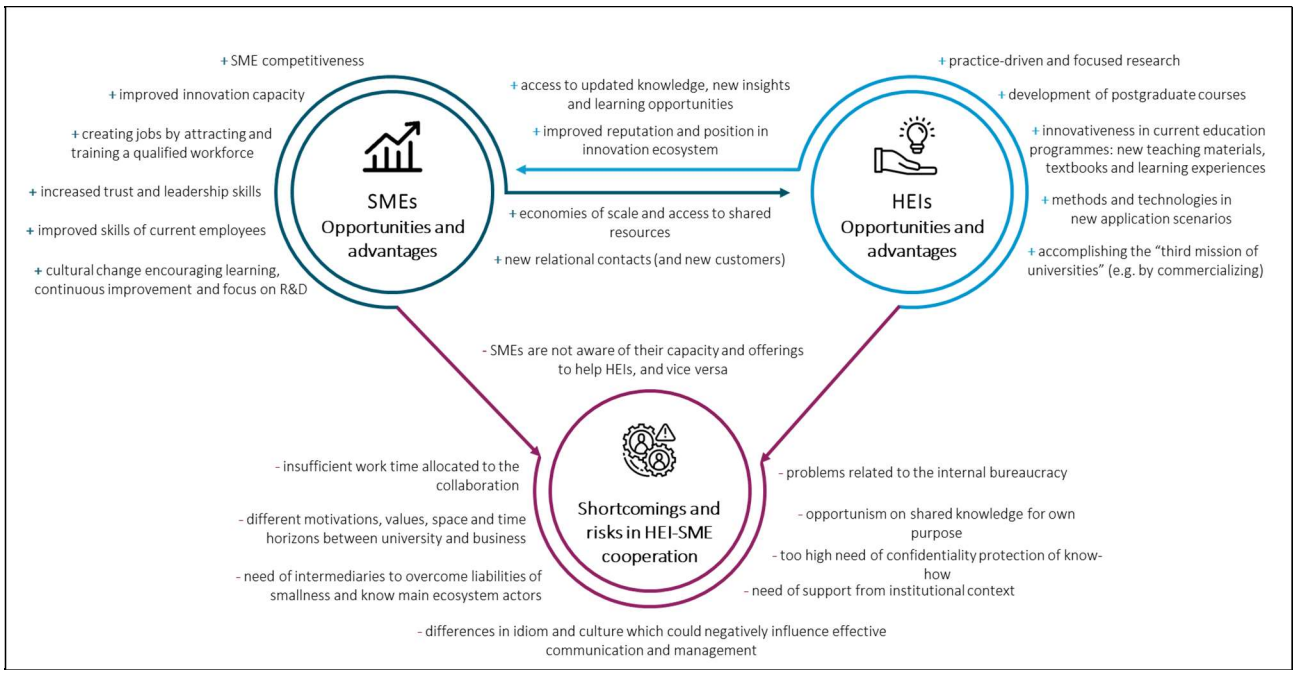

Figure 56: Opportunities and shortcomings of HEI – SME cooperation.

HEI-SME cooperation activities and channels

The European Commission identifies as key HEI-business cooperation activities (European Commission, 2018):

- research: collaboration in R&D performed within the company, within the HEI and/or in institutionalized practice environments (fieldlabs, living labs, …), consulting, mobility of staff;
- education: curriculum co-design, curriculum co-delivery, mobility of students, dual education programs, lifelong learning for business people;
- valorisation: commercialisation of R&D results, academic entrepreneurship, student entrepreneurship;
- management: governance, shared resources, university support.

Cooperation activities and channels specifically targeted for SMEs consider the importance of both formal and informal relationships and are identified in the figure below (Alunurm et al., 2020; Apa et al., 2020; Orazbayeva et al., 2019; SMeART University-Business Cooperation Model and Guidelines, 2019). These are grouped by type and involvement of human resources, i.e., students from HEI (🎓), employees from SMEs (👤), main strategic activities involving SMEs managers or the company in general (🏭) and HEI professors or the university as overall organisation (🏛).

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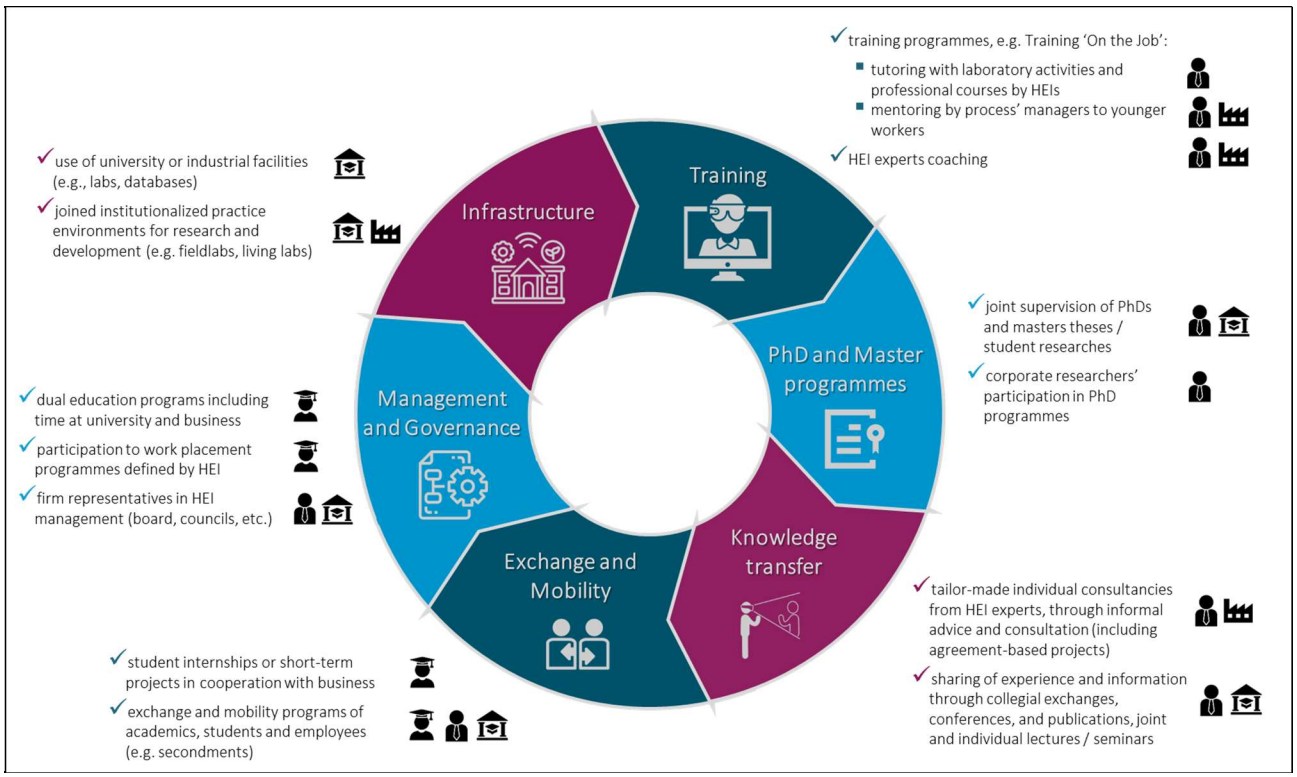

Figure 57: Activities and channels for HEI-SME cooperation

Examples of HEI-SME cooperation in AR/VR/MR

Some key examples and reference practices on issues and strengths of HEI-SME cooperation for AR/VR/MR are:

1. **Projects in cooperation with business:**

   TAMK Virtual Reality Sprint. Wake one and Tampere University of Applied Sciences created a new methodology based on Google design sprint to help students learn and apply XR technologies to solve real world problems. In a 5-day sprint student teams created functional XR prototypes based on actual company assignments (see more at: https://www.youtube.com/watch?v=wn4t3P3we6Q).

2. **Joined institutionalized practice environments for research and development:**

   Immersive Lab – Deus to University. The first university that created a Laboratory for students to experiment with XR technologies for master projects and thesis in collaboration with local AR/VR SMEs (announced on: https://www.deusto.es/cs/Satellite/deusto/en/university-deusto/deusto-a-unique-student-experience/deusto-and-virtualware-launch-a-pioneering-virtual-reality-lab/noticia?cambioidioma=si).

3. **Dual education programs including time at university and business:**

   Tampere University program courses. Students participate in excursion/learning trips to AR/VR SMEs and they are involved in jointly-organized short pilots with invited AR/VR providers (e.g. hands-on testing sessions with devices developed within their Labs).

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4. **Internships and training programs:**

   FIXAR project. Dutch universities and SMEs from the aviation and wind energy sector foresees SME employees training with AR/VR devices, internships and graduation projects for students, teaching factory sessions for SME entrepreneurs and the creation of new educational material for degree programs (https://inhollandcomposites.nl/fixar-new-automated-composites-repair-project/).

Check out also other EU-funded innovative projects aimed at cooperation, training and networking opportunities on AR/VR (the updated showcase of projects is available in VAM Realities platform at https://vam-realities.eu/related-projects/):

(1) **ARETE** - Augmented Reality Interactive Educational System (https://www.areteproject.eu/).
(2) **CLIPE** - Creating Lively Interactive Populated Environments (https://www.clipe-itn.eu/).
(3) **Digi2market** - Digital access to markets for sustainable rural business (https://digi2market.interreg-npa.eu/).
(4) **DIMPA** - Digital Innovative Media Publishing for All (https://www.dimpaproject.eu/).
(5) **VIRAL SKILLS** - Fostering Virtual Reality applications within Adult Learning to improve low skills and qualifications (https://www.viralskills.eu/en/).
(6) **Virtual Spitfire** - Using Virtual Reality and Local Industrial Heritage for Developing Key Competences (https://www.virtualspitfire.eu/).
(7) **VLFT** - Virtual Learning Factory Toolkit (https://vlft.eu/).

The VAM*Rs HEI-SME Cooperation model

VAM*Rs consultancy and coaching approach

Models help us to illuminate not obvious or very complex connections. They open ways of thinking to a more robust understanding of collaborative reflexivity, orientation, or examination of patterns. Those patterns will then be used as specified building plans, roadmaps or analysis framework for further use cases. It must be clear, that patterns or models are not made for themselves. The better a framework is represented, the better an adaption for, or preferably into the real existing world can be done. Imagination, reduction and of course also a rejection, which leads to new replacements or disruptive revolutionary ideas, are the main purpose (Rüegg-Stürm, J.; Grand, S. (2015), p. 40).

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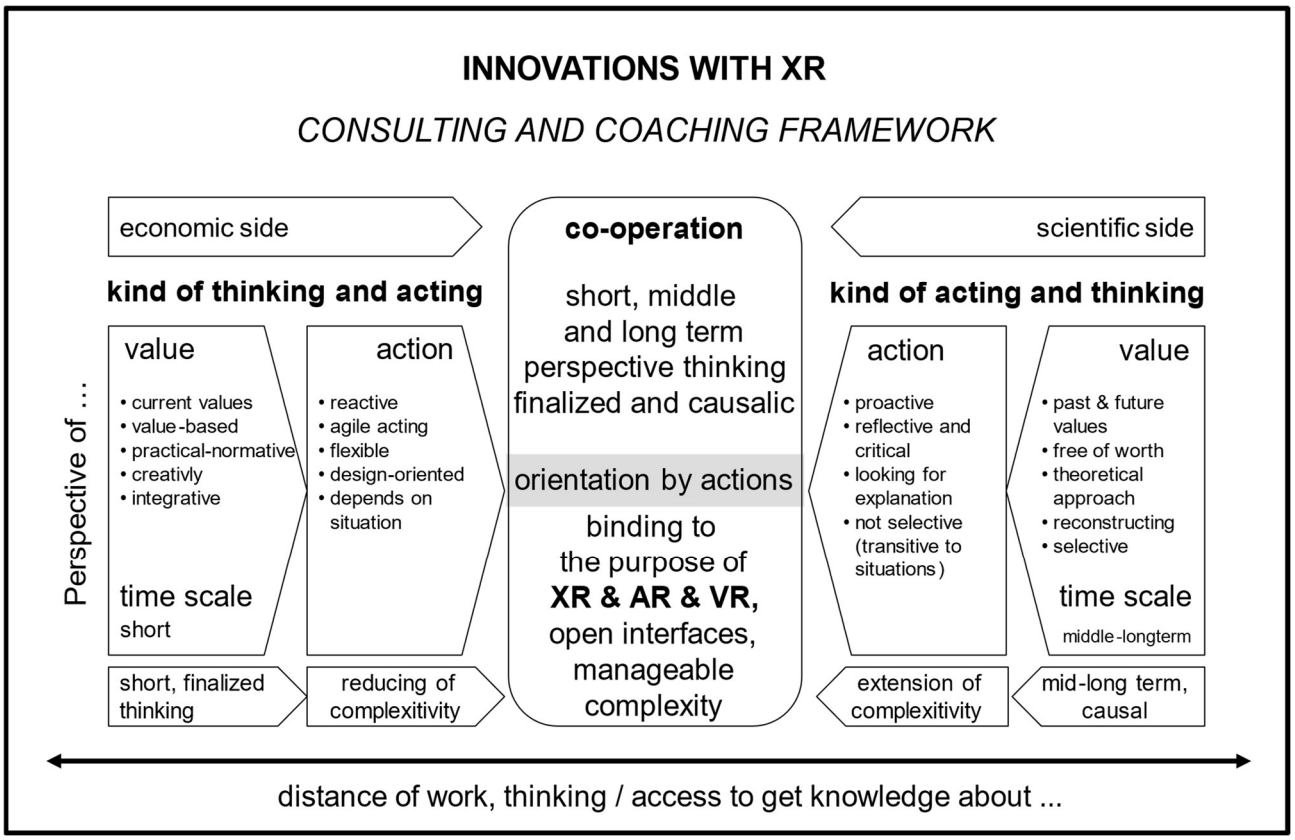

Figure 58: Consulting and Coaching Framework.
Source: adopted from Seisreiner, A. [1999]: Management unternehmerischer Handlungspotentiale, p. 157

The biggest challenge at the moment is to define the different levels of action, or rather fields of application of augmented and virtual realities (XR). With VR, the users are decoupled from the real world; with AR, the users remain in the original environment. The perspective representation of data, context-related with a specific information value, is to be interpreted differently in both worlds. If this fact is extended to include the variants of sources of disruption (in the real world):

- Speed of innovation (hardware, software, standards);
- Business models (demand, requirements, pull & push markets);
- Strategic thrusts (trial and error, volatile value propositions);
- Insufficient own resources and capabilities;
- Consolidations in industries, infrastructures or customer requirements. (Brettel, M.; Greven, A.; Kröckel, M. (2020)).

There is a conglomerate of uncertainties regarding technology, market development and competitive intensity. In the case of XR, one must at least still take into account the lack of evidenced historical data. The advisory and support program therefore concentrates precisely on these factors: reducing uncertainties, fixing horizons in a subject- and topic-specific manner, and providing simple parameters for adaptation.

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Services and adaptation offer - knowledge transfer in the context of multimedia and multimodal communication levels

The learning process is subject to constant change. In this respect, the concept of classical learning (frontal, direct, recording, repetition and application) is of secondary importance at the present time. The challenge is rather to localize the resources of knowledge, i.e. the sources, and to activate them in such a way that time, costs, quality and flexibility are adequately taken into account. In this way, an efficient and effective activation of change measures can take place in order to achieve the capabilities of the company or a business unit. It is important to understand that both providers of knowledge and consumers of knowledge-based services are no longer in a 1:1 relationship with one another (Puteanus-Birkenbach, K. (2020)). The participants find themselves in the form of visible or more or less invisible network structures in the learning and transfer process: project-related, ad-hoc, short to medium-term, very dynamic and adaptable. Both sides – providers on the part of HEI and recipients on the part of SMEs – inevitably have to deal with the questions of strategy, the virtual company form and the communities involved. The latter term roughly describes the function of the internet as a platform and communication channel. Regardless of time, space or level of education, knowledge holders with different intentions (for example, non-profit, cross-disciplinary, individuals as experts or groups of trendsetters) come together (Hartmann, M. et al. (2020); Howaldt, J., Kopp, R. (2007)). This is exactly where the challenge lies, namely in identifying and activating dynamic, fleeting knowledge that is only valid for a limited period of time.

Knowledge is context-relevant, situational, and therefore cannot be reproduced at will. In other words, a problem situation is always special and required a unique solution. The generalization of the variants, options and possibilities is limited, see model development. Interestingly, every type of knowledge also has a downside, which is characterized by the exponential growth in knowledge, its transformation and availability. The resulting complexity drives up the time and costs for the final selection of the core knowledge, which is the focus of interest (Howaldt, J., Kopp, R. (2007)). This is the distance as shown in the model above.

There are various models that describe the interplay between the corporate environment (e.g., suppliers, customers, government, and technology) and internal processes (innovation, business and organizational processes) in a virtuoso manner. It is generally important to reconcile a spectrum of requirements, processes, and results. The generation of value and the intrinsic value are determined by processes, i.e., the step-by-step sequence of individual tasks. These are, for example, innovation, product planning, product development, sales and order processing processes through to service processes (Trott, P. (2017); Schmelzer, H.J.; Stuhlmann, W. (2010)).

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Key elements to make an integration work successfully

Implementation should be made as simple as possible and divided into steps. The first step should be appointing qualified employees to familiarize themselves with the technology and train to use it. Then there are capacities that can implement it. In the next steps, you can go deeper because it has already been widely tested. In this way, capacities can be built up slowly.

Trust is very important here. If you have already worked with a university or network, the companies are very open and happy to accept the advice. If it is clear from the beginning that it is not a one-time short-term waste of money but a long-term benefit through a good concept, then the satisfaction is very high at every step.

SME readiness

In order for the adoption of XR technology to be successful, a few key factors have been identified that will ease the process and ensure a stable foundation for achieving success:

- A key factor in successful XR adoption is working with XR content, and content that is (already) created by the SME. Using a company's own content (such as 3d CAD models in VR/AR applications) helps companies to understand the capability of the technology, and whether AR or VR technology is better suited to the company and gives a sense of ownership and success to any XR adoption endeavor. Allowing the company to customize their own XR content is very rewarding in a learning experience.
- It is important to establish the capabilities of existing staff, their digital skills and affinity to using digital technology. It is important to identify key staff members who may have experience in related software, or perhaps have good potential to be trained to in using CAD software, 3ds Max, Blender, and gaming engines such as Unity and Unreal. If key staff cannot be identified then the likelihood is that external XR service providers will need to be used to create XR content for the company.
- Once a company is customizing their own XR content this will also give them a understanding of the workload involved and the investment of resources required to work with XR technology, and the resources required to use XR in different contexts. For example, the level of detail required in 3D models can vary dramatically. The requirements for 3D models for use in a collaboration design meeting in XR would be very different to the requirements for a slick animated 3D model to be used for marketing purposes at a technology fair or on a company website. The resources and

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investments required for each of these examples vary dramatically, as well as the workload and cost to convert these models into a format suitable for use in a VR or AR application. The workload is also dependent upon the capability the company requires in each situation, and the capability can often be dependent upon the performance capability of the VR/AR Platform.

- Perhaps even more important than the ability to create content, is the readiness of SME staff and of management to embrace new technology adoption. It is important to create awareness of the workload and resource investment involved in order to achieve a successful XR adoption. This involves a need analysis, and participation in selecting suitable hardware and software solutions for the SMEs, and the time required to get acquainted with this new technology.
- The success expectations of the SME must be managed, particularly depending on the digital readiness of the company and practical aspects, for example if numerous departments re involved in the XR adoption or in multiple locations.
- With staff and management willing to engage and learn, there must exist in the company and environment of innovation, an openness to risk and readiness to fail. Here it is again important to identify key staff who have experience, potential and/ personal interest in new technology, who are willing and permitted to learn about XR hardware and software and discover the capabilities of the technology. These individuals can be earmarked for further training, and they will be key to disseminating the new technology to management and colleagues and ensuring its sustained integration into the future.

HEI Requirements

It is difficult to design concepts when you are not yet fully aware of all the possibilities of AR/VR. A lot of help is needed here and the storyboards usually have to be created in close cooperation. Hands-on experiments with wide range of different hardware - without hands-on experience, it's almost impossible to understand the actual capabilities and limitations of different technologies.

What is needed?

- Content creation studied from multiple perspectives - understanding this is critical to be able to find a viable solution for a specific company.
- Ecosystems and their effect on software distribution, business models etc. - e.g. understanding the licensing models of Facebook/Oculus.

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- Explaining ROI: Often the costs are perceived as high because the added value or ROI is either not very clear or difficult to measure. Qualitative factors such as customer enthusiasm or innovation are difficult to measure and convert into numbers. Measurable value is added, when the staffs time is saved or error rates are reduced and more certainty of action is given.

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The VAM*Rs HEI - SME Consulting, Coaching & Cooperation Route map

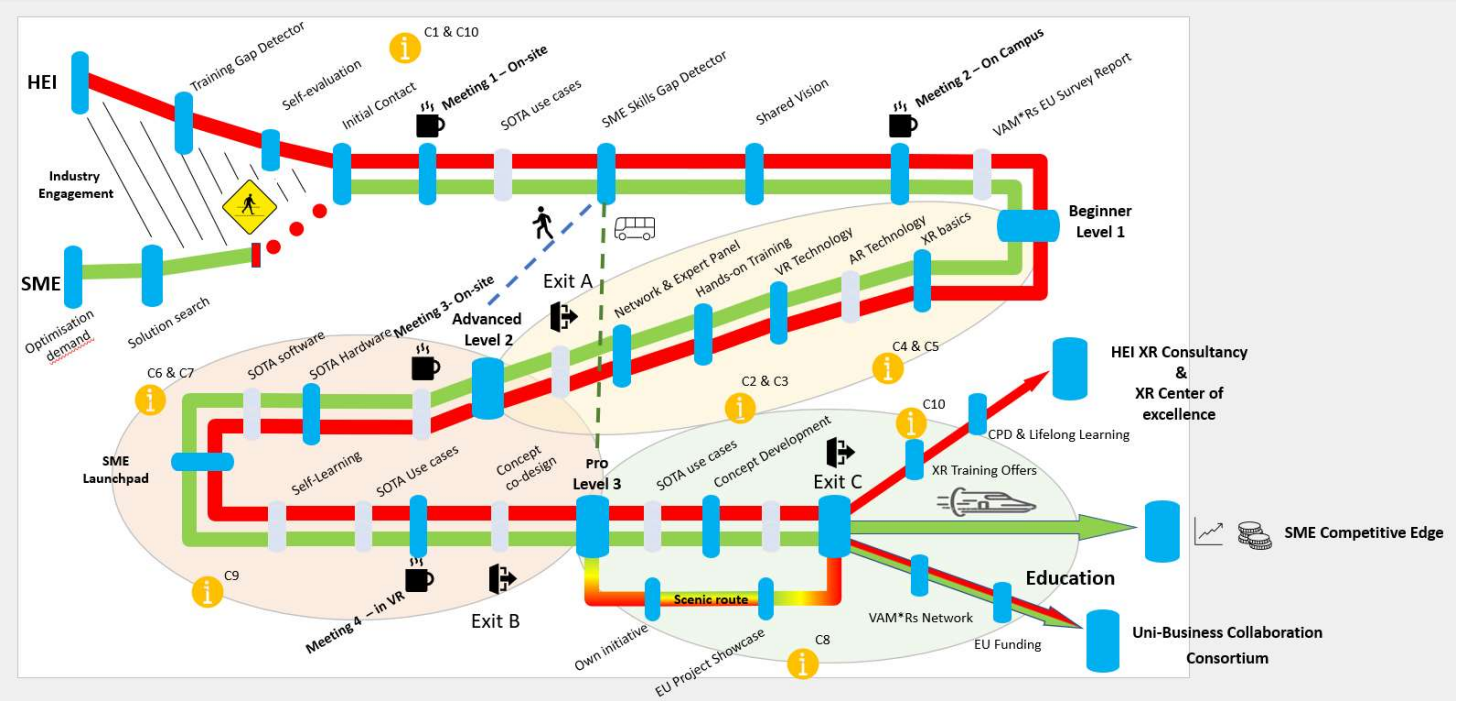

*Figure 59: The VAM*Rs HEi - SME Cooperation Route map*

Beginner Level 1		VAMRS Handbook chapter reference	
Advanced Level 2		Fast track to Advanced Level 2	
Pro Level 3		Fast track to Pro Level 3	
HEI-SME Meeting		Qualified Exit Point	

The above graphic is a visualisation of the ideal approach to the learning process of the VAM*Rs HEI - SME Cooperation model and a **route map** to implementation with suggested entry and exit points for accompanying SMEs at each learning level. It displays the potential finishing outcomes for HEIs and for SMEs in the cooperation process, and the comprehensive skills that can be acquired at each level. The route map is a simplification of an iterative process, to illustrate the progress learning steps and successful outcomes of the cooperation, in which achievements can be easily identified and the path to achieving each of these for the SME as client and the HEI as coach. The route map aims to visualise a clear step by step guideline to coaching for HEIs on their consultancy whilst coaching SMEs and how to utilise fully the accompanying VAM*Rs University Business Cooperation Handbook at each step, and how to make use of each of the VAM*Rs Tools that have been developed and at what point to introduce them. The route map clearly identifies the diverse levels of learning for SMEs, mapping out suggested Meetings and

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their locations, the suggested entry points for SMEs at each level of the VAM*Rs SME XR Coaching Program, and exist points for SMEs.

Review Meetings 

The route map sets out a series of suggested review meetings between the HEI and SME, and suggested locations for these occasions. Meeting 1 should be at the SME facility so the HEI can understand and experience first-hand the operations, challenges and needs of the SME. Meeting 2 should take place at the HEI campus, so that VR/AR hardware that may be on hand can be briefly displayed to the SME. Meeting 3 should take place at the SME so both partners, with their understanding of VR/AR, can contemplate where VR/AR can possibly be deployed in the facility. Meeting 4 should be held in a selected VR or AR application platform (such as Wake one XR platform), as this will test the learned technical skills of the SME.

Qualified Exit Points 

The XR SME Coaching program is structured within the route map that allows each of the three levels to be completed progressively, with the option to exit the program at three recommend exit points after completing a set learning level of the program (e.g., Beginner, Advanced, Pro). These levels of learning are highlighted in the route maps in an ellipse shape and are coloured coded. After an SME decides to exit, re-entry and continuation of the program can always begin then at the next learning level at a later time.

Fast track 

At the initial meeting of HEI and SME, a common judgement should be made about the knowledge and experience level of the SME in regard to XR technology. It is recommended that the SME also undertakes the VAM*Rs Skills Gap detector at this early stage. The recommendations and rating results from the Skills Gap Detector assessment and the judgement made after interacting with the SME, will give an affirmation to the most suitable level of entry to the XR SME Coaching program. The majority of SMEs should begin the program at the Beginner Level 1 stage, however if knowledge and experience are sufficient, selected SMEs way fast track to Advanced level 2 or even to Pro level 3. This will be at the judgement and discretion of the coaching HEI in agreement with the SME.

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Scenic Route

For SMEs that have a further interest in XR technology and wish to learn even more during the Coaching program, a selected amount of content from the VAM*Rs University Business Cooperation Handbook such as Chapter 8 (Legal and Regulatory challenges) are recommended, as well as exposure to the EU project Showcase and further range of available XR applications from the VAM*Rs State of the art report. These elements are optional, but all offer further in-depth knowledge for SMEs during the coaching program.

Outcomes

SME Competitive Edge: It is foreseen that when an SME completes each step in the route map of the VAM*Rs HEI -SME Cooperation model and the included three learning levels of the XR Coaching program, the SME will have obtained the necessary knowledge, skills and practical experience to adopt and integrate VR/AR technology in at least one area of it's operations. With the knowledge obtained, the SME can competently continue to integrate the technology into other areas of the business. This will subsequently over time high productivity, increase revenues and gain a competitive edge in the market place.

Uni-Business Collaboration Consortium: If the success of the HEI - SME cooperation wishes to be continued by both parties, the partnership can embark on future collaborations such as extensive research projects. The VAM*Rs network and the VAM*Rs EU project showcase are both highly valuable tools, in which the partnership can locate potential project partners within industry and academia who are active in current projects from across Europe. Once a consortium is established, project applications for potential EU funding programs for collaboration can commence.

HEI XR Consultancy & XR Center of excellence: During the completion of the route map and coaching program of an SME on VR/AR technology, the HEI will deepen it's experience and coaching ability through the guidance of the VAM*Rs University Business Cooperation Handbook and the other VAM*Rs tools. The HEI will also benefit from the ratings and recommendations of the VAM*Rs HEI Training Gap Detector (see below), and will obtain the necessary knowledge to get equipped, not only as competent consultancy in XR adoption for SMEs, but also to develop relevant training and study courses for full-time and part-time students that meets the needs of industry and address the growing importance of VR/AR technology to become an exemplary XR center of excellence, and set a new standards for other European HEIs to follow.

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Below is a list of the VAM*Rs tools and their recommended utilisation in the VAM*Rs HEI - SME Cooperation Model.

1. VAM*Rs European Survey

Contains key insights for HEIs and manufacturing SMEs on how XR technologies are currently being used and in what areas of the business. The Survey serves as a good introduction to how XR technology is adopted, and why similar SMEs in Europe are adopting.

Station: Meeting 2 & Beginner Level 1

It is recommended to introduce the general relevant elements of the Survey as an introduction to the topic and prior to level 1 of the XR SME Coaching program. This material helps to give SMEs a positive impression of the XR technology, to reduce barriers and illustrates the necessity to consider its adoption. For example;

- Why are AR and VR relevant for SMEs?
- How do European SMEs view the potential of each technology type?
- What is the status quo of current XR implementation in European SME and expected usage in the future?

Link: VAM Realities European Survey

2. VAM*Rs State of the Art report

This report begins with a brief introduction and explanation of the different XR technologies types - AR, VR and MR - and key terminology, which can be introduced at 3 different stations of the route map.

Station: Beginner Level 1 (Introduction)

Advanced level 2 (hardware and software reviews)

Throughout (25 use cases).

This report begins with a brief introduction and explanation of the different XR technologies types- AR, VR and MR, and key terminology. It is Recommended to use this explanation as part of the level 1 of the XR SME Coaching program. The report has an overview of XR technology relevant to SME currently on the market.

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Recommended to introduce the hardware and software reviews at level 2 of the XR SME Coaching program to help the SME understand the costs involved and the horizon of products that can enable the realisation of the SME needs.

The report includes over 25 use cases that vary in complexity and therefore suitable use cases can be used to illustrate the adoption of XR technology in SMEs at almost every learning level of the XR SME Coaching program and can be regularly introduced throughout the entire cooperation with increasing complexity to constantly illustrate the next possible step in XR adoption if the SME and HEI continue on the XR adoption journey.

Link: VAM*Rs State of the Art report

3. VAM*Rs SME Skills Gap Detector

The VAM*Rs Skills Gap Detector allows SMEs to self-assess their organisation for their technological readiness to adopt VR and AR technology into their business operations. This tool serves as a customised introduction to XR technology for SMEs and gives customised recommendations based on the inputted information.

Station: Meeting 1

It is recommended to introduce this tool to SMEs after meeting 1 between HEI and SME. The participating SME can conduct an online self-assessment or can do this with the guidance of the HEI. Custom recommendations and tips will be generated, and a 'rating' of the SME will be generated, that indicates the recommended entry level to the SME XR Coaching program, assisting the HEI in gauging the abilities and needs of the SME for the duration of the Coaching collaboration. As illustrated, based on the self-assessment and guidance from a HEI, the SME could be recommended to bypass Beginner Level 1 and fast track directly to Advanced level 2, if an SME is already skilled and knowledgeable or even directly to Pro level 3 if an SME is already very knowledgeable on the subject matter.

4. VAM*Rs HEI Training Gap detector

The VAM*Rs Training Gap Detector is an online, interactive self-assessment to be undertaken by HEIs who are planning to embark on XR Coaching collaborations with SMEs and for HEIs who aim to enhance the training and education offers and study programs to elevate VR/AR/MR technology awareness and adoption. The content of this Training Gap Detector is customized for program creators, directors/managers in HEIs. It is designed at assisting HEIs to provide convenient results towards developing a university course to create an XR expert. It helps to

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highlight what elements HEIs should consider bringing into their study programs and short-term training programs to fill the gaps on XR technology in business and industry. The Training Gap Detector results in evaluation, relevant recommendations based on given answers, potential research projects in this field for HEIs, and direct contact possibilities with XR experts.

Station: Pre-collaboration

It is recommended that HEI undertake the self-assessment prior to commencing Collaboration with an SME in XR adoption, so that they can first identify where training gaps lie in their own organisation and what and where improvements can be made to equip the HEI as a comprehensive partner of industry in the adoption of this technology.

5. VAM*Rs University-Business Cooperation Handbook

This Handbook is an essential part of the collaboration between HEIs and SMEs, and provides details on how XR technology can be integrated into various operations and work processes of manufacturing SMEs. The graphic clearly highlights with a yellow icon which chapter can be consulted and integrated at what point(s) of the cooperation. For example:

C 1 & C 10

Station: The tool can be integrated throughout the route map.

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6. VAM*Rs Expert Panel

The online platform is accessible via the VAM realities website and comprises of a mapped network of experts in XR technology and their application in different areas of industry across Europe. SMEs can use this resource to locate specific partners who can advise them on XR adoption in the specific area they are interested in and begin potential business cooperation. The expert panel is mapped across Europe and the selected experts can deliver expertise advice on XR technology but with local, regional or national knowledge relevant to the SMEs.

Station: Beginner Level 1

Advanced Level 3

Recommended to introduce the expert panel at level 1 of the XR SME Coaching program, to reassure SMEs right across Europe there is a large network of experts available to assist and support them in XR adoption. It is also recommended to introduce the experts panel again at level 3 of the XR SME Coaching program once the SME has a clear idea of their XR concept and may require further assistance or support in a specific field in order to implement their developed concept.

Link to VAM Realities Expert Panel

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7. VAM*Rs SME XR Coaching Program

The starting point of each of the three levels of the VAM*Rs SME XR Coaching Program is identified in the graphic. This is a recommendation of when to introduce to the cooperation the learning content of the pilot level. Each level is structured to accommodate all earning levels and in a progressive structure building on each level, so that the learner can always return to complete the remaining levels in the future.

The three levels each have a recommended station in the route map and their duration are marked accordingly:

Beginner Level 1	
Advanced Level 2	
Pro Level 3	

XR SME Coaching Program

The VAM*RS project has developed a XR SME Coaching program that will support and assist SMEs in the manufacturing sector to become acquainted with and integrate XR technology into their companies. The coaching program aims to integrate VR/AR technology, regardless of the level of an SMEs' familiarity with XR technology. The coaching program has been structured in a series of different learning levels to accommodate all levels of participants, in order to achieve tangible results for the participating SME.

In order to test and further develop the XR SME Coaching Model, the XR SME Coaching program has been offered in a pilot phase to SMEs in the manufacturing sector and hosted by the project partners of the VAM*RS project, across 8 different European countries from 2021 to 2022, including the following countries: Germany, Belgium, Italy, Finland, Cyprus, The Netherlands, Estonia, Spain.

Three level coaching system

The XR SME Coaching program has been structured in three different learning levels to accommodate all levels of participants regardless of experience and familiarity with VR/AR technology. The appropriate coaching level for each participant can be judged on the opinion of the participant in consultation with a representative from the VAM*RS project partnership, and furthermore the participants are recommended to undertake the VAM*RS SME Skills Gap Detector, which is available on the VAM*RS project website. Participants will receive an analysis of their companies VR/AR technology awareness and a recommended entry level point to the

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VAM*RS XR SME Coaching program. The 3 levels of coaching available in the VAM*RS XR Pilot Coaching program are as follows:

1. **Beginner: XR boot Camp (12 months planning horizon)**

   For participants and SMEs with little or no experience of VR/AR technology nor familiarity with its capabilities for business and industry. Participants will be learning the basics of XR concepts and how XR can be used in industry as well as a hands-on basic training in XR hardware and software. Technology.

2. **Advanced: XR SME Launch Pad (6 months planning horizon)**

   For participants and SMEs with limited experience of VR/AR technology and are low level of familiar with its capabilities for business and industry. Participants will discover sector-specific uses cases and how XR is applied to each area of business as well as receiving training in 3 state of the art XR applications to create customized XR content for their SME.

3. **Professional: XR Business Concept (3 months planning horizon)**

   For participants and SMEs with extensive experience of VR/AR technology and seek an individual concept and solution for their company. Participants collaborate with coaches on the development of a custom AR/VR Solution for your SME, including a concept development and implementation Plan.

Accessibility

The XR SME Coaching program has been established as part of the VAM*Rs project and participation will be made free of charge to suitable SMEs during the lifetime of the VAM*Rs project. Appointments and a training schedule, and training locations will be available on the VAM*Rs project website for the program will be continuously updated and refined based on feedback and evaluation during and after the lifetime of the project. Please check the project website for full details www.vam-realities.eu.

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Graphic of VAM*RS XR pilot Training Coaching

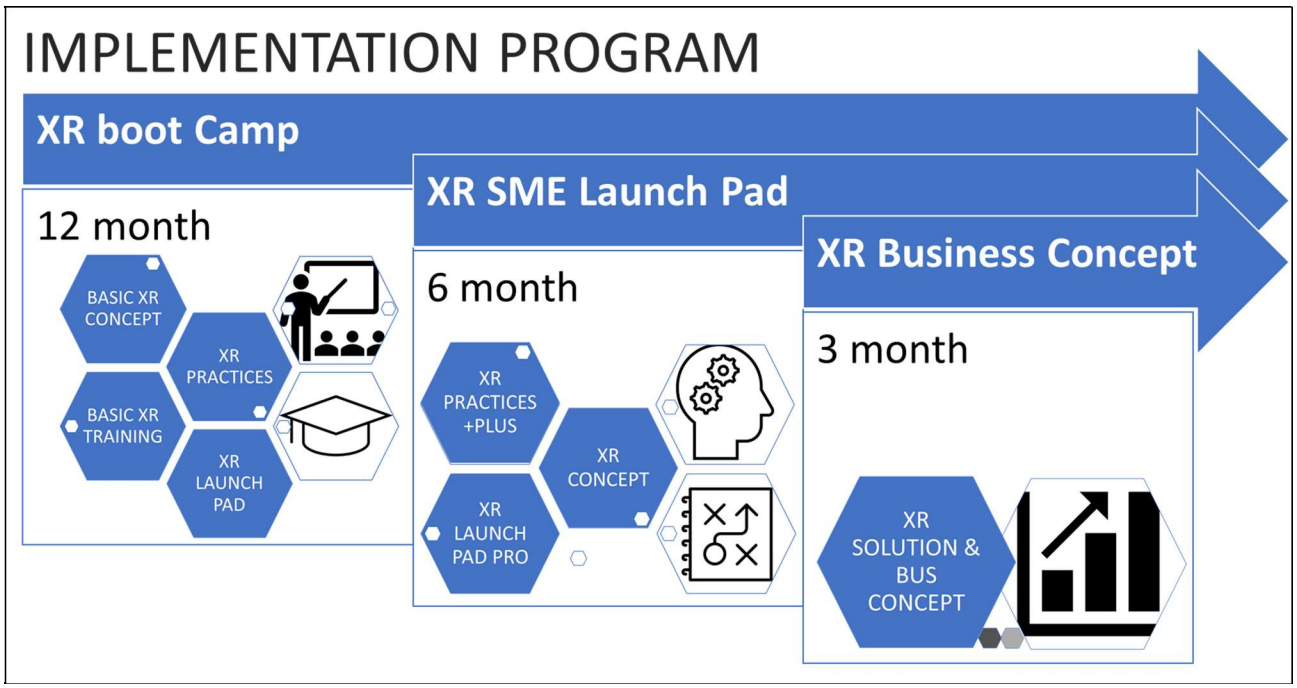

Figure 60: VAMs Training and Coaching Programm

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Training

Despite AR and VR represent rapidly growing and evolving technologies and their expanding application areas highlighted the demand for highly qualified specialists in this field, both teaching competence and exchange of good practices in the field are still very fragmented and a literature primarily focused on teaching aspects of AR/VR is still missing (Klimova et al., 2018). Learning outcomes include both theoretical and practical competencies and skills concerning AR/VR software and hardware, related devices, mathematical and programming aspects of these systems but, beside these theoretical and professional skills, they also include a set of different and various soft skills. HEI can support SMEs through the development of different training services and according to a series of program areas addressing the multifaceted issues connected to the adoption of new enabling technologies, such as AR/VR (Klimova et al., 2018).

What kind of training services can HEI offer?

Figure 61: Possible training services

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Specifically, Training 'On the Job' can include:

- tutoring with laboratory activities and professional courses carried out by university researchers
- mentoring by process' managers (already trained by the university experts) to younger workers.

Learning Formats for VR/AR training and education

When flexible learning opportunities are adopted by HEIs allow for individuals from business and industry to enhance and improve their skills and knowledge whilst maintaining full-time employment. Employees can upskill and stay updated on developments such as VR/AR, and employers and SMEs benefit from highly skilled employees that maintain a competitive advantage and assist SMEs in retaining key staff. Often such learning opportunities integrate practical elements that are more familiar to industry such as workshops, conferences, e-learning programs and use best practice examples.

Flexible learning opportunities also allow a formal interaction between SMEs and their staff from industries with academic staff and researchers from HEI. This can lead to fruitful exchanges and beneficial cooperation.

Lifelong learning - Programs and services contributing to lifelong learning within the higher education sector may include mainstream programs, continuing education, evening classes, specific programs for part-time learners, access to libraries/higher education institution resources, distance learning, training courses, targeted guidance and counselling services among other actions and initiatives.[95]

Continuing Professional Development - Continuing Professional Development, CPD describes the skills, knowledge and experience that an individual gains formally and informally in his work and which builds on his basic qualifications and training. Increasingly in professional and vocational careers there is a formal requirement to continue to learn and develop knowledge, skills and competences throughout careers to keep up to date and be able to work safely, legally

95 https://ec.europa.eu/assets/eac/education/ects/users-guide/glossary_en.htm#lifelong-learning, 21.08.2021

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and effectively. Formal CPD which is a professional requirement is validated and documented. Increasingly employers expect to have a formal authenticated record of an individual's CPD and it consequently has become an important element in the curriculum.[96]

Encouraging the use of Micro-credentials

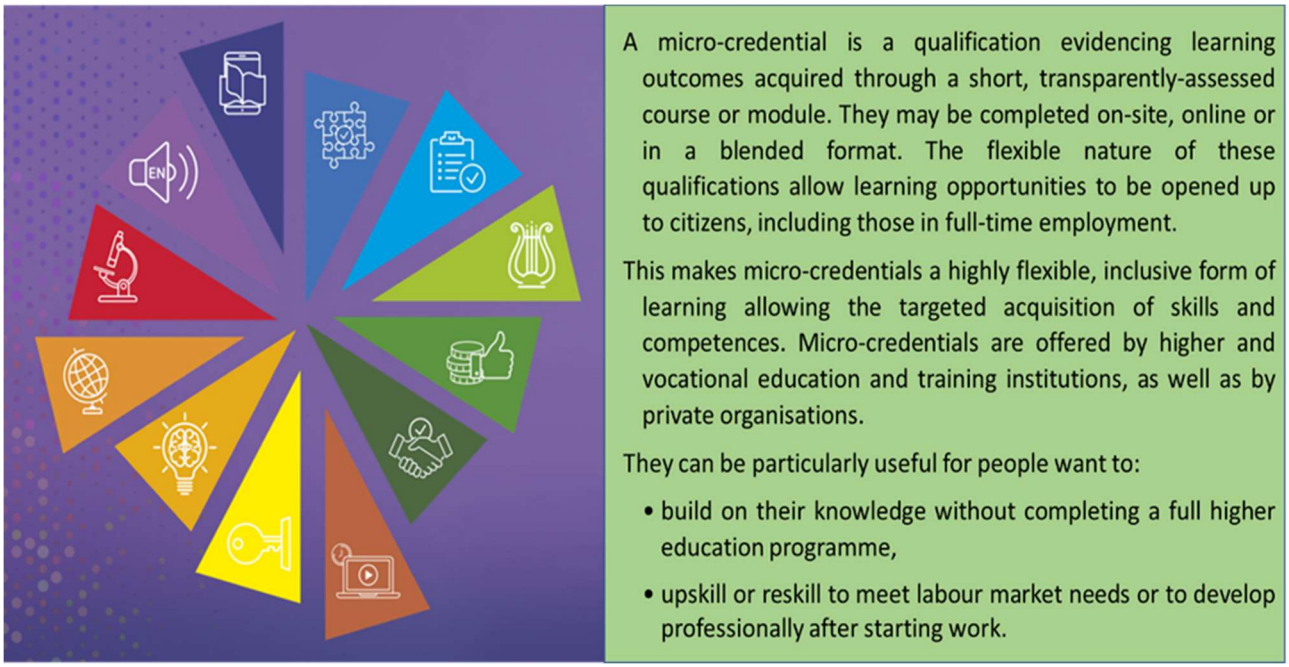

Figure 62: Micro-credentials - What is behind all the idea?

Micro-credentials can be delivered in online, face-to-face, or blended formats and can be as stand-alone units of learning or structured in a sequence of courses that can be embedded eventually within, or cumulate into, a larger credential. Further, micro-credentials can be used for complementing conventional qualifications as part of lifelong learning and continuous professional education, and as pre- and post-graduate education (Cirlan, E.; Loukkola, T. (2020). This sets at least a simplified working framework for a HEI/SME specific coaching process.

96 https://ec.europa.eu/assets/eac/education/ects/users-guide/glossary_en.htm#lifelong-learning, 21.08.2021

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The introduction of XR into everyday study, training and workplace environments cannot currently be compared with a plug & play system, as is known, for example, from the entertainment electronics, mobile phone or computer industries. Not yet! The virtual technologies are going through these exhausting first development phases in order to evolve from the corner of the niche application to a broadly effective, known and accepted standard technology. The variety of applications is so large, that the best recommendation for training and coaching to be made here can only be: reduce the core messages to simple, comprehensible statements. Less is more. Small steps, less complex examples. Activate the imagination of your users or target groups. Ask for the ideas and thoughts. Everything that does not yet seem technically possible may be available soon. Or vice versa: the technology has to improve one thing or the other here.

For example, identify the following points for a coaching and learning program:

- Level (and possibly cycle) of the learning experience, which later also leads to micro-authorization (EQF and / or national qualifications framework; overarching qualifications framework of the European Education Area),
- current and future learning successes,
- the form of participation in the learning activity (online, on-site or mixed, volunteer work, work experience),
- What are the requirements for registering/participating for the learning activity?
- Type of assessment (exam, application of a skill, portfolio, advanced levels and recognition of previous learning, etc., see for example Micro credentials),
- Quality assurance and feedback loops for standardization and adaptation.[97]

So learning how to use XR has something to do with a general approach to lifelong learning. Universities are called upon to rethink and redefine the relevant entry barriers, e.g. technical terms, time pressure, studying behavior, helping people to help themselves, etc. XR will - in

[97] Final Report – A EUROPEAN APPROACH TO MICRO-CREDENTIALSOUTPUT OF THE MICRO-CREDENTIALS HIGHER EDUCATION CONSULTATION GROUP December 2020, p. 13 https://ec.europa.eu/education/sites/default/files/document-library-docs/european-approach-micro-credentials-higher-education-consultation-group-output-final-report.pdf, 21.08.2021

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connection with the micro credentials that will have to be considered more in the future - represent an attractive field of activity.

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What XR-related training program areas should HEI invest in?

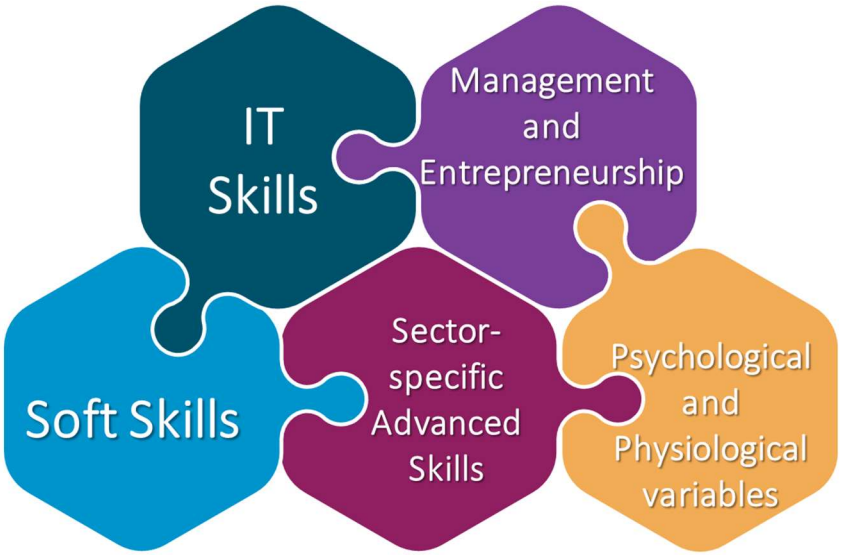

Figure 63: XR training program areas

The VAM*Rs project has highlighted some key knowledge and skills that SME require to adopt and integrate VR/AR technology into their operations and processes. HEIs that wish to assist and support SMEs in this action, will benefit from integrated and adding the following suggested trainings, course topics and study programs to their education offers, to both full-time students and part time learners from industry.

Examples of specific program areas are:

IT skills	• SW development (including maintenance and updating) • Mathematical and Programming (AI) • Basic concepts and training in Virtual & Augmented Reality • IT system integration • VR/AR in adoption industry & commerce • 3D Modelling: Standard VR in industry & commerce industry CAD software (AutoCad, Siemens NX, SolidWorks, Inventor, Creo etc) • 3D Animation: Standard software for Animation (Blender, Autodesk, 3Ds Max etc) • 3D creation platforms: Standard game engines (Unreal engine, Unity etc) • Computer Science

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Management & Entrepreneurship:	• Digital Business, focussed to analyse and identify new business opportunities in the new technologies sector and possible use cases (also calculating ROI) • Digital marketing • Business processes reengineering/optimization/management • Product Management • Scrum product ownership • Agile project management • (Technology) Innovation management (including understanding the licensing model of HW/SW) • Access to facilitation measures (Tax Credit, EU Funding programs (e.g. SME instruments), …) • Digital Marketing & Sales • Data protection management • Product Management • Business Administration
Soft skills	• with an interdisciplinary approach to digital transformation • Critical thinking • Building training (e.g. Gamification)
Sector-specific advanced skills	• Design and engineering • KPIs definition and monitoring • Business processes optimization • Industry 4.0 • Mechanical and industrial Engineering • Business Information System (BIS)
Psychological and physiological variables	• Ergonomics & Digital tools • Health and safety training

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Towards a more effective training of SMEs in AR/VR

Starting with AR/VR demands a special set of knowledge, skills, competences, mind-sets, attitudes, infrastructure, and investments for SMEs. It is taken for granted that this will also require innovative approach in business consulting and HRD. Consultancy and training offered to SMEs needs to fulfil the following requirements:

- Provision of consultancy and training in small units,
- Each unit needs customising to different target groups within one company (management, HRD experts, IT experts, workers etc.),
- In-house services should be preferred,
- Training plans needs to be flexible (including possibilities for short-time changes),
- Avoidance of too much theoretical or scientific background information,
- Clear benefits and ROIs have to be communicated,
- Focus needs to be put on application-oriented and practicable sessions (rather than explaining VR/AR/MR, it should be demonstrated in practice) with hands-on experiments and the live use of AR/VR devices,
- Content creation studied from multiple perspectives.

Virtual coaching and training

To facilitate better learning and training activities, the use of online resources has been adopted for education purposes. Implementing electronically based approaches, learning and training can be conducted at anywhere and anytime, in a cost and time efficient manner. Virtual coaching and training are even more important due to the challenges raising from Covid-19 pandemic in terms of both practical and geographical restrictions. E-learning is basically a set of on-line educational services, teaching and helping to improve students and trainees nowadays seen as the most important form of distance learning. Thanks to the popularization of e-learning systems, many companies have developed computer-based training programs for their employees with advantages over traditional learning methods (Lalic et al., 2017). Emerging media, such as simulations, serious games, and in particular immersive ones, as virtual worlds, and augmented reality, enable a level of immersion and interaction previously unavailable, thus

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improving tangible learning outputs (Abulrub et al., 2011). Moreover, some learning activities can be completed offline (Chang, 2016).

A novel form of Virtual Learning Environment is represented by MOOCS: massive open on-line course (MOOC) is an on-line course aimed at unlimited participation and open access via the web. Politecnico di Milano, for examples, offer a set of MOOCS for professionals, as the POLIMI OPEN KNOWLEDGE (POK), based on the Open-EDX platform.

What's around: examples of virtual coaching and training

Different forms of hands-on education and training can be adopted according to specific target public and purposes basing on virtual and augmented technologies. For what concerns Vocational Education and Training, including lifelong learning for vocational functions, some options are represented (SMeART University-Business Cooperation Model and Guidelines, 2019) in the figure below.

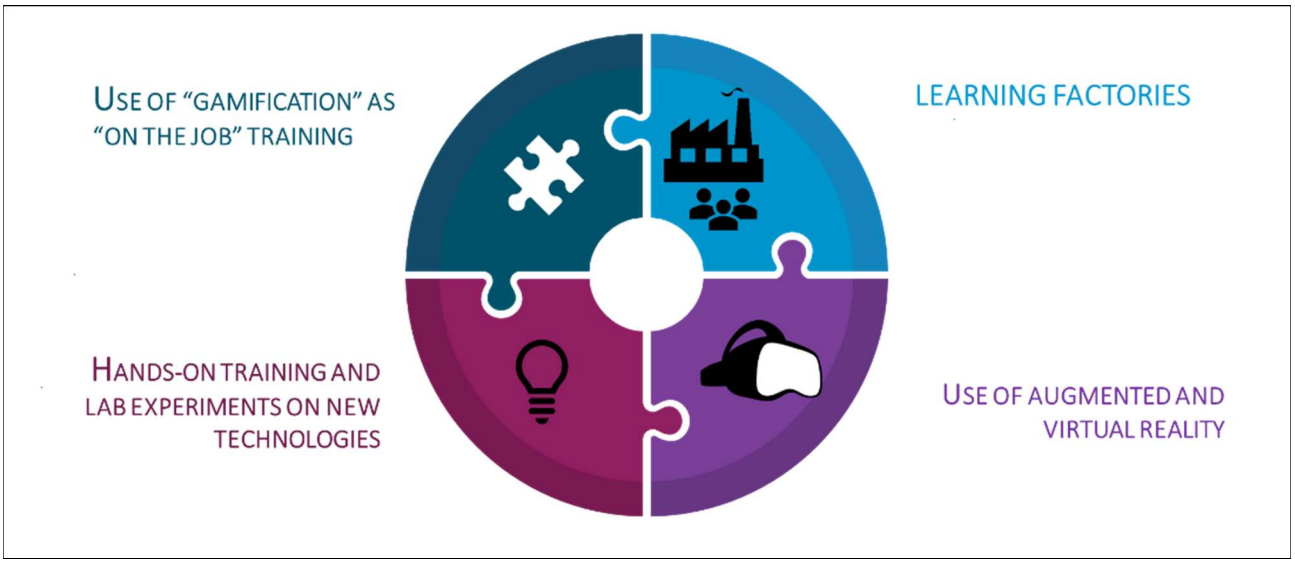

Figure 64: Virtual coaching and training

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Conclusion

University-Business Cooperation is considered to be the engine towards knowledge-based societies and economies. The engagement in collaboration with universities is shown to have a positive impact on the innovation performance of SMEs, and an effective adoption of innovative solutions such as AR/VR technologies. Both SMEs and HEIs should consider the major opportunities and many possibilities for cooperation in XR (adoption) projects. **The VAM*Rs HEI - SME Consulting, Coaching & Cooperation Route map** is a visualized approach to the learning process of the **VAM*Rs HEI - SME Cooperation model** and a guideline to implementation of XR within manufacturing SMEs. It is a tool for HEIs to accompany, coach and train SMEs at each defined XR-learning level: Beginner, Advanced or Professional. It displays the potential entry points and finishing outcomes for both HEIs and SMEs in the cooperation process, and the comprehensive skills that can be acquired at each level by suggested training formats, tools and programs. The VAM*Rs Roadmap shows how to utilise fully the accompanying *VAM*Rs University-Business Cooperation Handbook chapters* at each coaching step, and how to make use of the other developed *VAM*Rs Tools* -like the State-of-the-Art Report (SOTA) and the Skills- and Training Gap Detectors- at each step of the consulting, coaching and cooperation process.

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