Output 2 from the MixTec project

Technical analysis of the use of VR/AR in continuing vocational education and training (CVET).

Status: 28.04.22

Erasmus+

Nationale Agentur beim Bundesinstitut für Berufsbildung

NABIBB BILDUNG FÜR EUROPA

Content

Output situation

First, we would like to address the following initial question:

How can XR[1] be used in the instruction/training of technical specialists for SMEs?

In principle, XR applications can be divided into the two main categories of **virtual reality** and **augmented reality.** In virtual reality applications, real situations are completely simulated and the user can interact with the virtual environment in these simulations. In augmented reality applications, on the other hand, the real world is merged with virtual elements. Here, previously defined markers are used to enrich the real situation with context-sensitive information via a digital end device (tablet, smartphone, AR glasses) (e.g., the fade-in of the position of a maintenance flap on the real device).

The two basic variants of XR applications can be divided into subcategories. These are determined on the one hand by the combination of technology and end devices, e.g.

- Virtual reality with headset or on laptop
- Augmented reality with AR glasses or on the tablet

and on the other hand depend on the respective application, e.g.

- AR support Call via video telephony or AR app as interactive assembly instructions in the tablet.

This results in the following need for clarification:

- **Target groups** for use
- **Scope for** the training
- **Technological framework of** the XR used
- **Relationship between technology and scope**
- **Relationship between technology and target group**
- **Software and hardware provider**

Target groups

Which target groups come into question and how promising is the offer of an XR application for the respective target groups?

[1] We understand "Extended Reality" (XR) as an umbrella term for all forms of virtual reality and augmented reality, including, for example, 2-D virtual reality or augmented reality on the tablet.

In our opinion, XR can be used for any target group in a technical trade. Whether these applications can also lead to a positive cost-benefit calculation, however, remains to be clarified. The following is an exemplary list of target groups with possible fields of application.

Target group	Fields of application
Trainee	▪ Learn basic skills and processes (e.g. correct tool use, safety training, ...) ▪ Exercises and assessment of learning content with automated feedback
Technicians/Specialists	▪ Further training content (new techniques, processes, equipment handling) ▪ Troubleshooting and maintenance with the help of an AR application ▪ Assembly instructions/commissioning for devices
Master craftsmen/engineers	▪ Further training content (new techniques, processes, equipment handling) ▪ Remote troubleshooting via AR call to local expert ▪ XR application as a resource for service and sales

The relationship between target groups and technologies

If you are planning to use digital support for a specific target group, it is worth investigating their digital competence and their general affinity for digital applications in advance. The following questions should be used in this consideration:

- Is digital content perceived by the target group more as a motivational booster or dampener?
- Does the target group already have experience using the hardware (smartphones, VR headsets, AR glasses, etc.) or will a learning phase be necessary?
- How is the general digital competence of the target group assessed? Specifically: Can it be assumed that the target group will also quickly get to grips with new digital applications and the associated hardware or not?
- Is there certain hardware that the target group is already particularly familiar with, e.g. daily use of a laptop, or are they "digital natives" with smartphones and tablets?

<u>As a rule of thumb, the following can be stated:</u>

The less the engagement with digital content and the associated hardware will motivate the target group, the more the decision for the technology used should depend on the fit to the target group and not on the fit to the purpose.

Scope

Which fields of application are there and which type of XR is practicable for the respective use?

In principle, it is also true for this question that the XR offers a diverse range of possible fields of application. From complete virtual reality applications to special augmented reality apps and enriched remote support calls, a wide range of application scenarios can be found in technical work areas. In the following, the most promising uses and open questions from our point of view are listed.

No.	Scope	Notes / Examples
1	Knowledge transfer (as opposed to competency development) and automated assessment in initial training.	▪ Well suited for the visualization of 3D models ▪ Assessment possible in combination of real execution and AR support (automated feedback difficult/expensive). ▪ Added value to "normal" e-learning or other classic forms of teaching questionable ▪ Knowledge is in most cases more easily/better conveyed through other media
2	Further training for new techniques/devices/processes	▪ Getting to know a new task via VR application or AR application→ virtual instruction manual ▪ For safety-related activities VR or 2D VR (on laptop) well suited
3	Commissioning and maintenance of equipment	▪ Virtual assembly instructions (Ikea instructions in XR) ▪ AR applications to follow step by step instructions
4	Ad-Hoc Troubleshooting and Remote Support	▪ Via AR support calls with the possibility to solve a problem directly by a remote support technician in a video call ▪ AR glasses are probably best suited here (hands free and cues directly in the field of view) ▪ Possibility to highlight critical process steps at the moment of execution (e.g. pay attention to the correct assignment of a plug at this moment) ▪ Laypersons may be able to perform higher value/more complex technical activities

If one looks at the above-mentioned areas of application and considers them more closely in relation to the question of suitability for further education, training and education, then it is important to make certain distinctions. Thus, with regard to the learning process, the following criteria (cf. Rauner, 2011) can be used to differentiate:

Competence level

- Nominal (superficial conceptual knowledge)
- Functional (elementary professional knowledge and skills)
- Processual (references to operational work processes)
- Design (consideration of operational and social framework)

Learning area

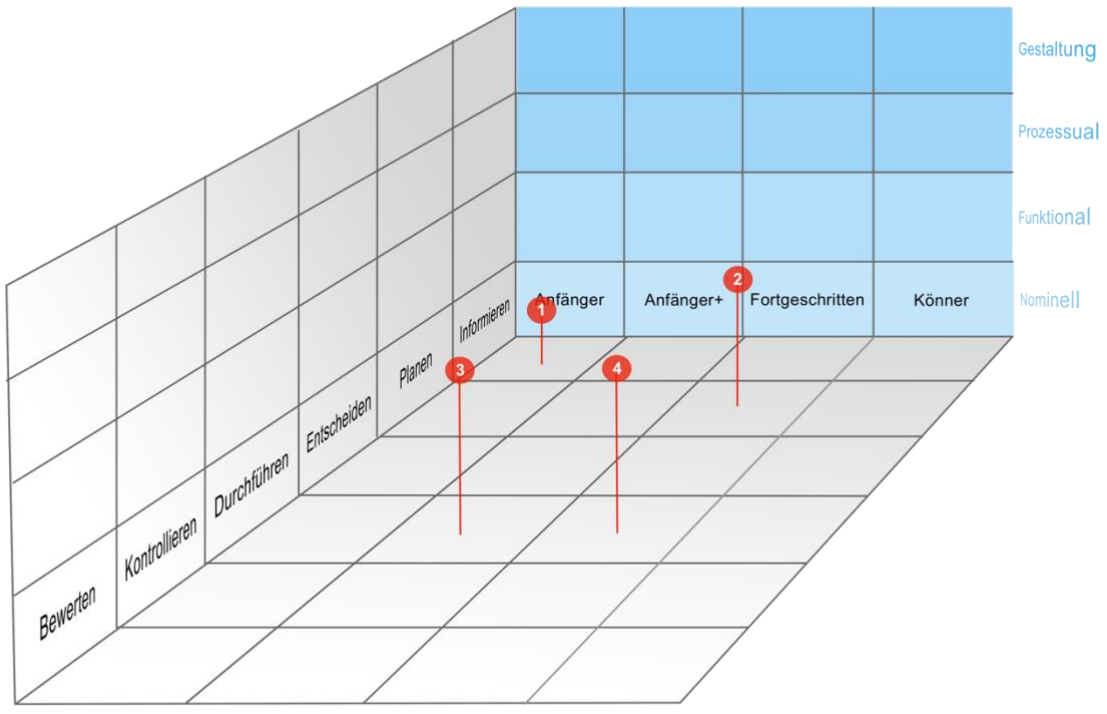
- Beginner tasks
- Advanced beginner tasks (Beginner+)
- Advanced tasks

- Skill tasks

Action dimension

- Inform
- Plan
- Decide
- Perform
- Control
- Rate

In the following graphic, the exemplary application areas mentioned above are arranged on the criteria matrix. It is striking that none of the suitable application areas goes beyond functional competence. It can therefore be assumed that the promising fields of application for XR do not lie in competence development, but rather in guidance and guided implementation.



Technological framework

What possibilities and limitations come with the different XR variants?

In principle, XR applications can be divided into the two main categories of virtual reality and augmented reality. In virtual reality applications, real situations are completely simulated and the user can interact with the virtual environment in these simulations. In augmented reality applications, on the other hand, the real world is merged with virtual elements. Here, previously defined markers are used to enrich the real situation with context-sensitive information via a digital end device (tablet, smartphone, AR glasses) (e.g., the fade-in of the position of a maintenance flap on the real device).

The two basic variants of XR applications can be divided into subcategories. These are determined on the one hand by the combination of technology and end devices, e.g.

- Virtual reality with headset or on laptop
- Augmented reality with AR glasses or on the tablet

and on the other hand depend on the respective application, e.g.

- AR support Call via video telephony or AR app as interactive assembly instructions in the tablet.

However, for the question relevant here, it is sufficient to simply compare the two basic forms in summary form and list their advantages and disadvantages.

Virtual Reality

Advantages	Disadvantages
▪ Very real experience of simulated situations ▪ Especially well suited for security-related topics ▪ The experience of environmental factors (altitude, noise, movement) can also be simulated well ▪ Can be used on headset as well as on laptop (but with less intensive experience of the simulation) ▪ A development with the development environment "Unity" allows the use on almost all hardware end devices	▪ High development effort, as an entire virtual world is created ▪ Rapid wear and tear of the hardware and unreliability of the VR headsets ▪ It can take a long time to learn how to use the VR headsets ▪ Use as 2D VR on a laptop cancels out an important advantage of VR (complete immersion in a simulation) ▪ Headset VR applications require the hardware. If this is not on site, use is not possible. ▪ Only suitable for practice, cannot be integrated into the work process (asynchronous and not context-sensitive) ▪ Compute-intensive application, so 2D VR also requires either powerful laptops or good internet connection for server-side deployment ▪ Headset VR applications can cause dizziness with prolonged use

Augmented reality

Advantages	Disadvantages

▪ Very well suited in combination with external support via telephone or data line ▪ Cost-effective production of content/applications ▪ Many end devices can be used directly (smartphone, tablet) ▪ Can be provided independent of location ▪ Embedding in the work process well possible (direct or almost direct linking of instruction and application) ▪ There are many providers of basic platforms for creating and deploying AR applications ▪ Can be learned more quickly with an application via smartphone and tablet	▪ Are context sensitive, but can only react automatically to changes in the real world with a lot of effort ▪ Function only in combination with the real environment→ No learning simulation possible ▪ Require reference points in the real environment (e.g., QR code) to achieve higher-order integration with the environment ▪ AR applications without glasses lose the great advantage of having your hands free ▪ The use of AR glasses is quicker to learn than VR, but still takes its time

In addition, there are overarching issues for both XR variants that can influence the added value or cost-benefit balance. These include the following points, among others:

- What costs are incurred for programming/provision of the applications? In some cases, the software providers have to be paid not only once, but again and again via subscription contracts.
- How well/badly can the applications be revised, adapted or extended?
- Software-Hardware Restrictions: Are there any restrictions regarding the use of the software with certain hardware (e.g. only certain applications for the AR glasses of a certain provider)?
- Are 3D models already available for the relevant devices/workpieces? If not, the development effort increases enormously.

Technical analysis

The relationship between scope and technology

Which XR variants are best suited to which application?

In terms of the fit between the application area and the XR shape, there are some combinations that fit without any problems. For other application areas, the target group plays an important role in determining whether they are suitable. In the following, therefore, some suitable case studies for a sensible combination of application area and technology are briefly explained.

Remote support with AR glasses

An experienced engineer at the company's headquarters provides support via a video call to repair a device at a remote location. A technically skilled person, who does not have the necessary expert knowledge, is guided through the repair process by the connected remote support. The use of AR glasses is well suited for this purpose, as the local expert can directly implement the instructions of the remote support and both participants can see the same thing. By being able to superimpose the image for the local specialist in the direct field of view, the remote support can not only describe the process and the necessary action steps, but also make them directly visible for the local specialist.

Safety training with VR headset

A new specialist is to learn the necessary safety measures, e.g. maintenance at great heights. Here, a VR headset is used to simulate the complete maintenance situation for the specialist, including the experience of his own high position, the movement of the environment and the wind noise in the VR experience. The skilled worker practices the maintenance process in a safe environment, but under realistic environmental conditions. In case of errors, the professional is protected and thus better prepared for the first real operation.

Interactive commissioning with AR on the tablet

The manufacturer has provided virtual operating instructions for setting up and commissioning a new device. The customer's specialist uses his own tablet for this and is guided step by step through the assembly of the device. A small QR code on the device itself is scanned with the tablet as a reference point at the beginning. The specialist can then display the next steps and the position in the real room on site on the tablet and carry them out step by step. Critical action steps or possible sources of error can thus be highlighted directly during the set-up process with notes.

Maintenance process exercise with VR on laptop

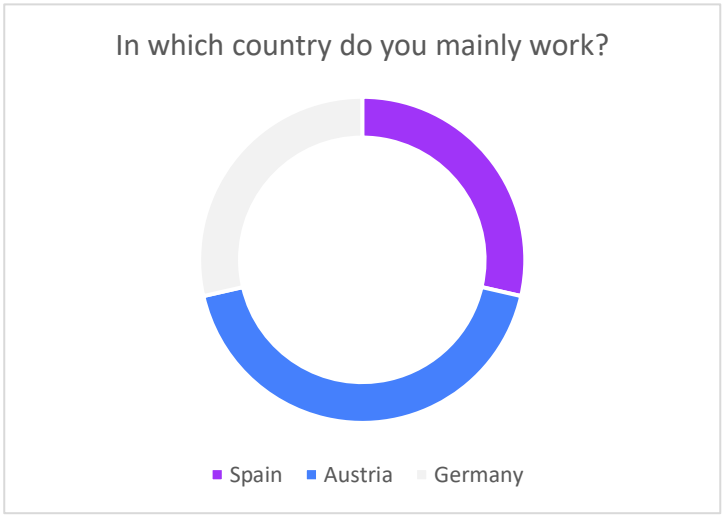
A field service employee is to be prepared in advance for the maintenance steps on a new machine. For this purpose, the specialist is provided with a 2D VR program on his laptop. The specialist can then internalize the necessary maintenance steps at his own pace and practice them in the simulation. Although it is not possible to practice the actual steps (e.g. loosening a screw), the specialist can identify the sequence and critical points in the maintenance process in advance and thus better prepare for the actual maintenance.

In conclusion, this results in an initial combination table of the various XR shapes and frequent application areas.

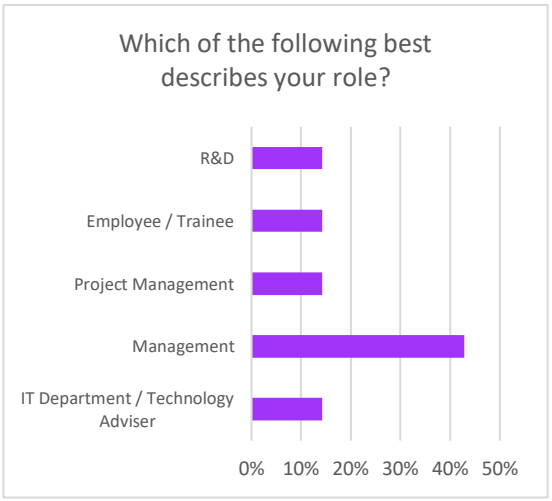
	Virtual Reality		Augmented reality	
	Suitable for	Unsuitable for	Suitable for	Unsuitable for
With headset / glasses	▪ Safety training ▪ Simulation of environmental conditions ▪ Practice of action sequences	▪ Support for work processes ▪ Field use ▪ Assembly instructions/commissioning ▪ Remote support	▪ Remote support ▪ Support for work processes ▪ Interactive operating instructions / maintenance instructions ▪ Synchronous guidance and implementation ▪	▪ Safety training ▪ Simulation of environmental conditions ▪ Practice of action sequences ▪
With laptop / tablet	▪ Safety training ▪ Practice of action sequences ▪	▪ Remote support ▪ Simulation of environmental conditions ▪ Support for work processes ▪	▪ Field use ▪ Remote support ▪ Interactive operating instructions / maintenance instructions ▪ Fast support on your own device ▪	▪ Safety training ▪ Simulation of environmental conditions ▪ Practice of action sequences

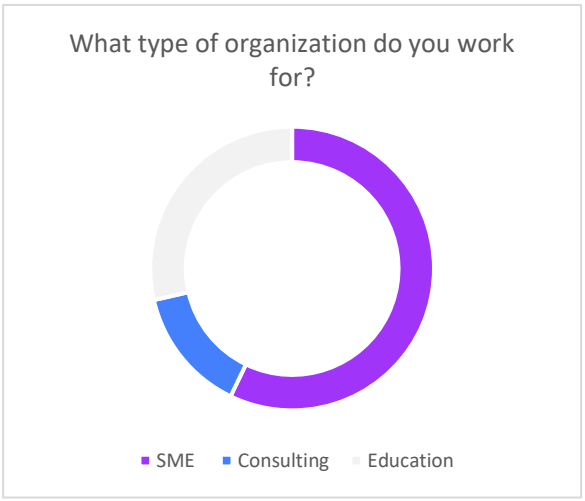
General information about the survey

In order to gain a better overview of the relevant technologies, the fields of application and the advantages and disadvantages of different XR technologies, a survey study was conducted. The survey was offered in German, English and Spanish and distributed in the network of the Mix-Tec project[2] .



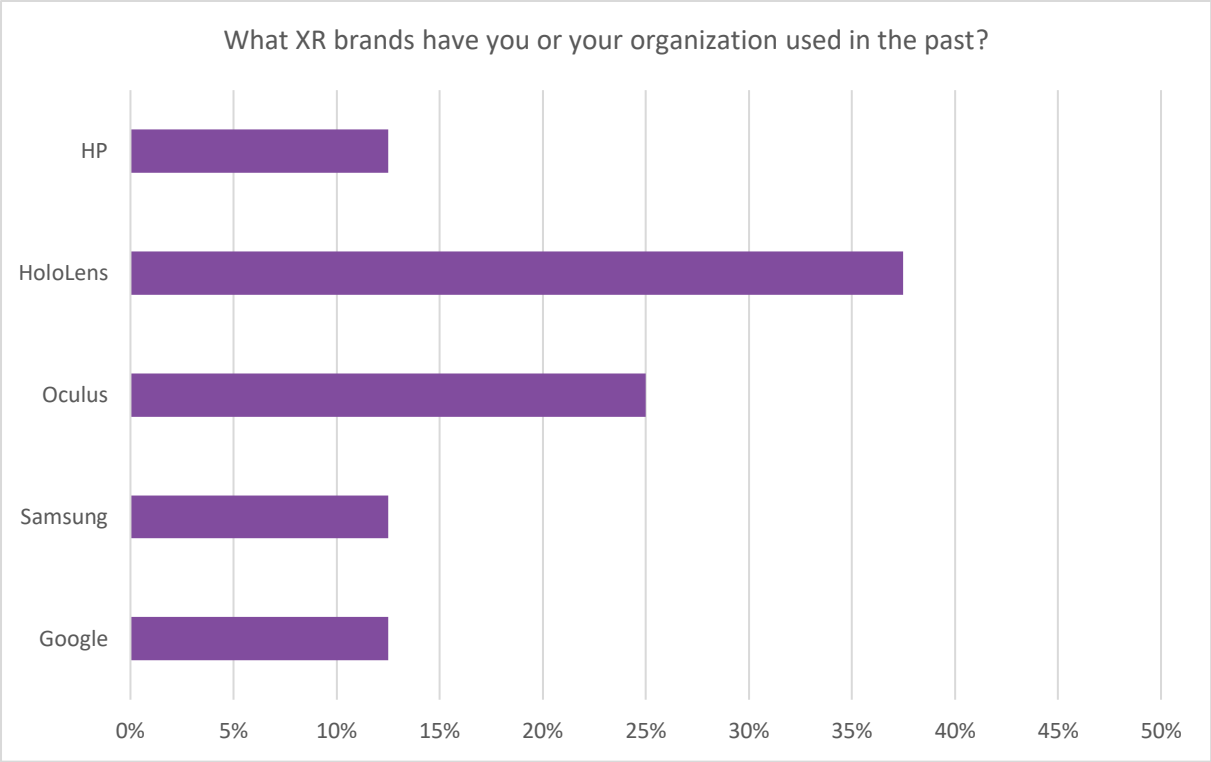
The participants were mainly people from small and medium-sized companies who work there in management.





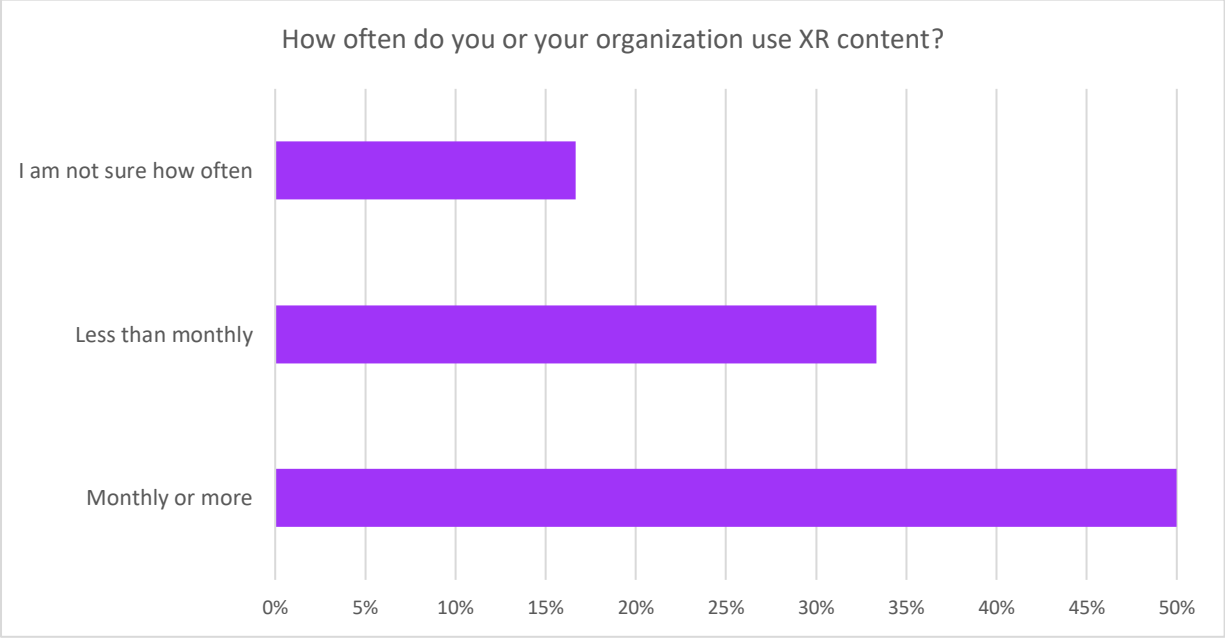
The most used XR brands seem to be HoloLens and Oculus Rift:

[2] Due to the multilingual nature of the responses, the results were processed in English and are also presented here in this language in the results graphics. A total of 18 people participated in the study, so the results can only provide a cursory overview of the relevant topics.



Analysis of the target group

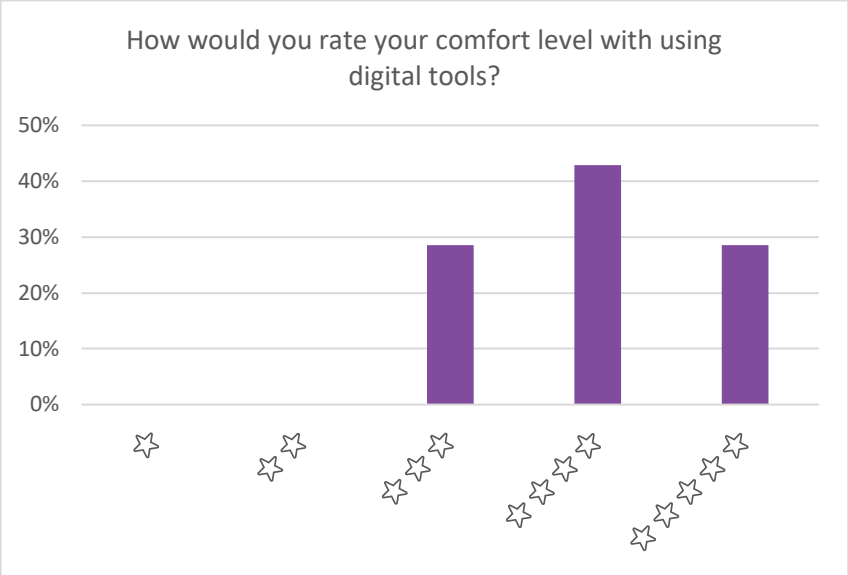
With regard to the dissemination of XR technologies in the participating organizations, a relatively high usage rate was found. Although this is presumably not representative of the spread of XR in SMEs in general, it does show that the sample can demonstrate concrete and real experience in the use of XR.



In order to find a better overview of the participants' approach to the technology, some questions were collected to better assess the group. In summary, the following can be stated:

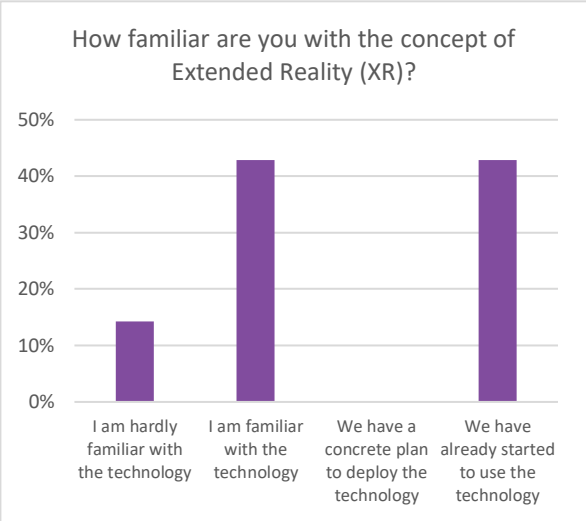
- All participants have already used XR apps

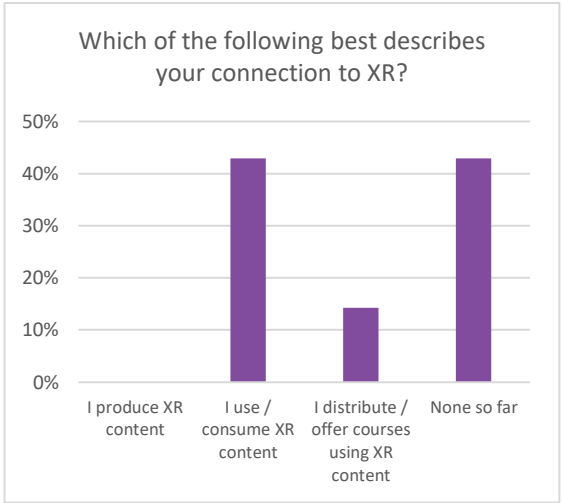
- Participants are more familiar than average with the use of digital tools in general
- Most participants work in an organization that uses XR regularly



Overall, the XR users from our sample can be classified into two groups:

Scoper	Distributor
▪ Has knowledge of the technology ▪ Has no specific plans to use it in the future	▪ Has knowledge of the technology ▪ Consumes/distributes but does not create





Advantages and disadvantages for the use of XR

During the survey conducted, the following elements were identified as beneficial features of XR applications:

Item	Rating
Enables participants to safely learn hazardous operations	★★★★★
Awakens participants' enthusiasm and commitment to learning	★★★★½
Possibility to look at unclear content more often	★★★★½
Makes difficult concepts easier to learn	★★★★☆
Encourages creativity in participants	★★★½☆
Allows participants to attend from anywhere	★★★½☆
Lower travel cost in comparison to face-to-face trainings	★★★☆☆
Eliminates distractions during lesson	★★☆☆☆

The survey conducted identified the following elements as potentially harmful features of XR applications:

Item	Rating
Requires customized didactics to work	★★★★½
Not enough content yet	★★★★☆
Difficult to implement	★★★★☆
May cause dizziness	★★★½☆
Too expensive	★★★½☆
Too difficult to handle during training	★★★☆☆
May cause headaches	★★★☆☆
Could be a distraction	★★★☆☆
Too much like a game	★★½☆☆
It isolates participants	★★☆☆☆

Conclusion

In summary, as an analysis from the sample responses, the following software can be listed as helpful in creating XR content:

- Focus on Vuforia Studio in combination with Thingworx
  - High costs; difficult to implement for SMEs
- Dynamics 365 remote support
  - Microsoft subscription
  - In combination with MS Teams

The following cases are identified as suitable fields of application:

- Visualization of data from IoT platforms
- Create step-by-step instructions

- VR - dangerous and expensive operations
- AR/MR - real-time support (remote assistance)

When can the cost of XR applications be justified?

Possible providers of XR applications	Cost-benefit consideration
SME: Focus on providing XR applications for own employees and customers. For internal training, field service support or service offerings to customers (remote support, virtual maintenance and operating manuals, etc.).	The applications must allow for high savings elsewhere (travel costs, downtime, training) because of the relatively small number of deployments. VR will only be financially viable if the device data is already available as 3D files. If necessary, independent programming.
Training centers: focus on providing XR applications for trainees from different employers (high number of participants, generalist content, focus on learning and knowledge transfer, performance inquiry and assessment)	Even higher costs, e.g. for VR, are justifiable if the applications, e.g. in standard training/learning units, can convey knowledge more forcefully or more easily understood. Easy changeability is important if content is to be adapted.
Industry associations: focus on providing XR applications for continuing education of members and marketing purposes (high show value, generalist content, directly visible continuing education benefits)	Applications that can be used without additional hardware (headsets, data glasses, etc.) are important in order to reach as many interested parties as possible.

(IT service providers / agencies: focus on programming and providing XR applications for various customers. On a contract basis or subscription model)