BEST PRACTICE GUIDE

Using Extended Reality (XR) and XR haptics in craftsmanship training

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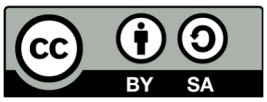

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1. Preface

Digital technologies are our daily companions at work and in our private life. They come with a lot of promises. Digital enhanced training solution in vocational education and training need to come in handy twofold: from a technical and a pedagogical perspective. A difficult use prevents a further integration in training as a lack of providing a measurable pedagogic added value does as well.

It is necessary to understand where modern technologies like Augmented Reality (AR), Virtual Reality (VR) and Virtual Reality haptics are best to use for. They should be easy and safe to use and improve the learning of apprentices mainly before and during practical training.

During craftsmanship training hands-on experiences are an integral part. This is especially true for crafts like: bricklaying, carpentry, parquet laying, and painting.

In this best practice guide we will explain you WHAT AR, VR, and VR haptics is, and HOW they can be applied in pedagogic-sound way in practical craftsmanship training. This will help you to transfer our learnings easily into your classroom and into your workshop.

2. Initial situation: HOW question first, WHAT question second.

The extent to which trainers apply new technologies correlates to the quality and effectiveness of education. Therefore, it is necessary to treat AR, VR, and VR haptics as educational technologies, concerning providing a pedagogic value-added during training provision. Starting points in the XR4CRAFTS project, where the following educational questions:

Bricklaying (VR, VR haptics):

1. How to apply Virtual Reality to support a guided learning when laying a brick wall before carrying it out in reality?

Carpentry (VR, VR Haptics):

1. How to apply Virtual Reality to support self-directed learning during sanding operation with a router?
2. Can provide Virtual Reality haptics a more realistic training to support the knowledge transfer into training practice?

Parquet laying (VR, VR haptics):

1. How to apply Virtual Reality to support self-directed learning during parquet laying?
2. Can provide Virtual Reality haptics a more realistic training to support the knowledge transfer into training practice?

Painting (VR, VR haptics, AR):

1. How to apply no-code AR solutions to support self-directed learning as well as increase collaboration during carrying out the work?
2. Can provide Virtual Reality and Virtual Reality haptics a more realistic training to support the knowledge transfer into training practice?

3. Pedagogical implications

The key question in the XR4CRAFTS project was: “What is the **pedagogical added value** of AR, VR and VR haptics in practical training in craftsmanship?”

In recent years, the effects of these technologies on learners have been analysed from a rather technological point of view. Media-pedagogical perspectives are underrepresented. In addition, AR, VR, and VR haptics are new technologies in vocational education and training.

Augmented Reality is the choice for instruction-led trainings of technical skills and the provision of professional knowledge by e. g. pre-defined learning paths.

Virtual Reality excels for the repetition and the training of work activities, which are too dangerous or too expensive.[1] Beyond training, the construction of own virtual worlds and the self-driven exploration of inaccessible spaces (geography, simulated travels in the past and human body) are further fields of application. The explorative aspect supports the acquaintance of declarative knowledge, and it results, if uninstructed, in learning strategies on a trial-and-error basis.[2]

VR haptics is a part of Virtual reality. It enriches it by adding sensation like tactile or kinesthetic feedback. It allows to “feel” in VR to increase the immersion and training the muscle memory. Scenarios could be self-directed of expert-led.

[1] Buchner et. al, 2020, „Lernen mit immersiver Virtual Reality: Didaktisches Design und Lessons learned“, Zeitschrift für Medienpädagogik 17, 195-216. (DOI: 10.21240/mpaed/jb17/2020.05.01.X)

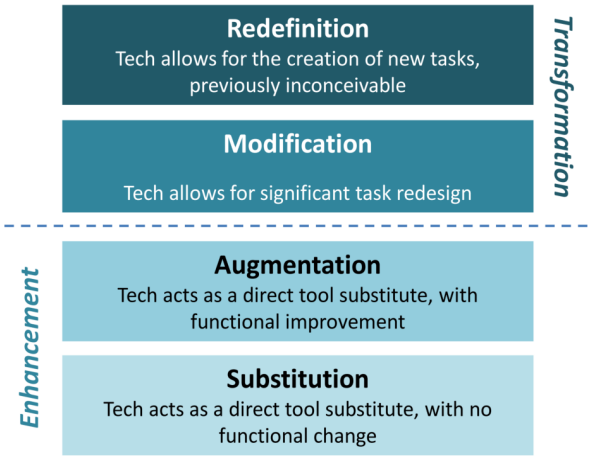
[2] Zender et. al, 2020, „HandLeVR: Action oriented Learning in a VR painting simulator”, 46-51, in: Popescu E., Hao T., Hsu TC., Xie H., Temperini M., Chen W. (eds) Emerging Technologies for Education. SETE 2019. Lecture Notes in Computer Science, vol 11984. (DOI: https://doi.org/10.1007/978-3-030-38778-5_6)

4. Step-by-step: pedagogic models to consider

To successfully implement a new technology within vocational education a three-step approach is recommended.

Step 1: Decision about augmentation or transformation?

New technology can have manifold impacts, ranging from a substituting or augmenting technology. If technology allows the redesign or the creation of new tasks the transformative level is reached. The **SAMR-Model** (**S**ubstitution, **A**ugmentation, **M**odification, **R**edefinition) provides a classification framework (see below).

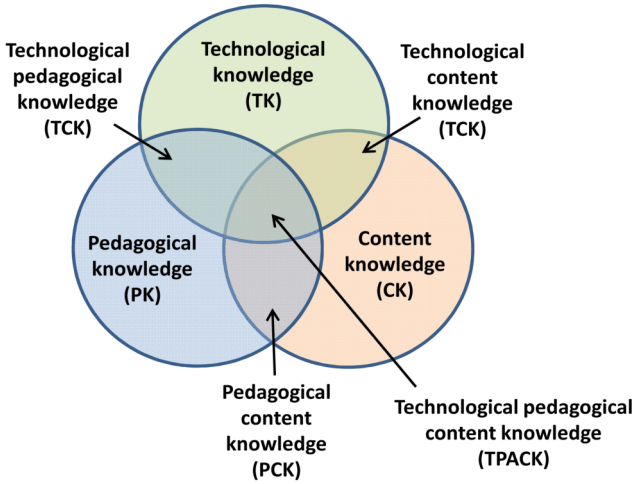


AR, VR, and VR haptic to augment a course.

Step 2: Decision on sound combination of technology, pedagogy, and content?

A teacher or trainer needs knowledge of:

- Content - What lesson content does he or she want to offer with AR, VR, and VR haptics?
- Pedagogical possibilities - In which way and in what form does he or she want to use AR?
- Technology - How should they use AR, VR, and VR haptics?



The **"TPACK' model** ('technological pedagogical content knowledge') provides a framework what to look for when planning a lesson. It helps to integrate and to harmonize pedagogy and technology in lesson planning and during lesson execution. This helps apply teaching and learning principles as well as technology in relation to the most effective methods for a given field and type of content.

STEP 3: Decision on what are the learning objectives?

The integration of AR, VR, and VR haptics in a specific lesson demands a careful description of the desired outcomes. They can reach from the provision of e. g. technical knowledge to the enrichment of communication and collaboration as a teaching method. The focus in practical training for is for:

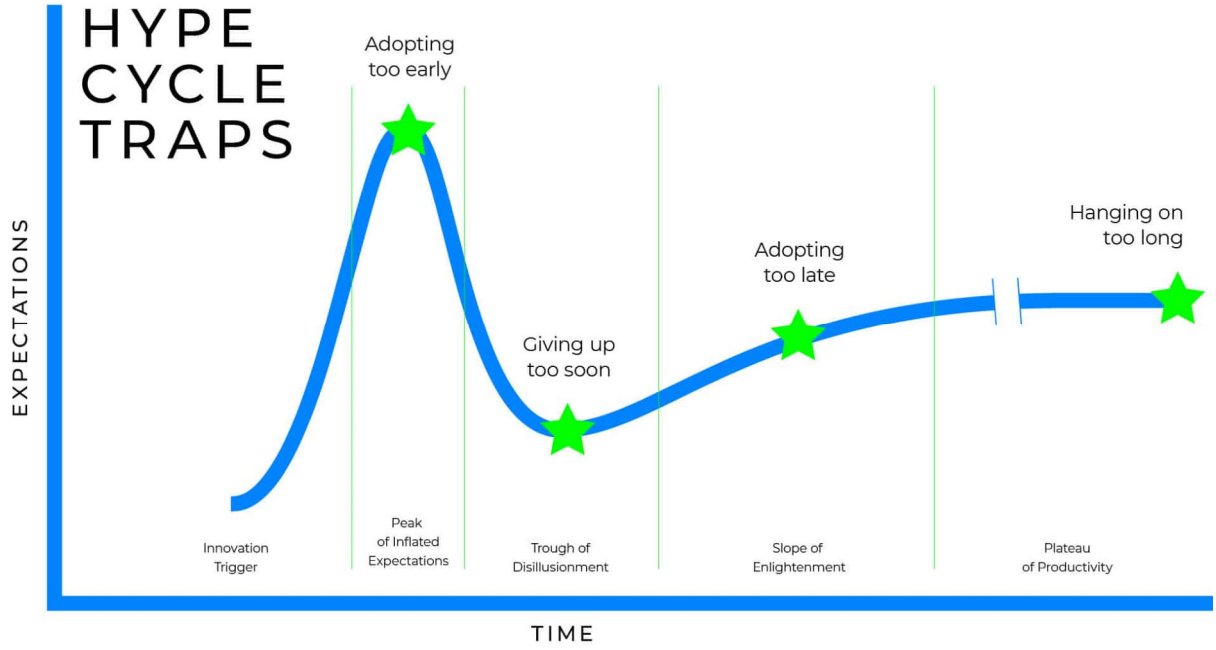
a) AR rather on activities such as "**clarify**", "**carry out**", "**integrate**" or "**judge**".
b) VR rather on activities such as "**recognize**", "**recall**", "**summarize**" or "**classify**".
c) VR haptics rather on activities such as "**classify**", "**clarify**", "**carry out**".

After the definition of the expected impact (augmentation), the integration of the relevant knowledge (TPACK) and the clarification of the learning objectives the enrichment of the relevant learning environment with the supporting communication and collaboration scenarios can be carried out.

5. Hard- and software

The development of smart glasses happens in a very dynamic environment. The technology is not new one. In recent years, the glasses got more accessible due to advances in computing and in storage media. The bottleneck is the availability of suitable and professional content for working and learning environments in industry and craftsmanship

Each new or modern technology surfs the hype cycle[3]. Boosted by high expectations, entering the period of disillusion and in the best case proving to be productive. The consulting firm Gartner publishes each year a hype cycle of new technologies. AR and VR were found on it until 2018. Both technologies graduate from the Hype Cycle from "a technology to watch" to one to use.[4] Gartner predicts "immersive workspaces" and „augmented intelligence" since then.



The industry is driven by economies of scale. When starting the project in 2022 Meta Quest 2 (300 €) was dominating the market.

Decisive factors for the purchase of an VR glass are:

- Price
- External computer needed or not
- Battery duration
- Weight
- Control: by the help of controllers or by voice
- Available learning content

This led to the selection of the following devices in the project:

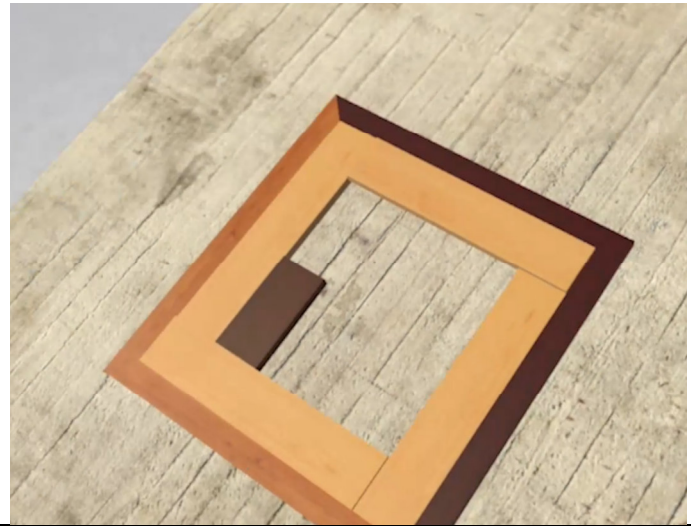
[3] https://viraloctopus.com/magazine/strategy/gartner-hype-cycle-technology-adoption-curve/
[4] https://arpost.co/2020/09/25/augmented-reality-gartners-hype-cycle/

Meta Quest 3

To carry out VR haptics suitable Haptic gloves were selected. We decided for the affordable Bhaptics Tactgloves (USD 300 per pair). The look and feel like safety gloves, as well as they provide a tactile feedback (vibrations). Gloves with a tactile and a forced feedback were also considered but price (around 6000€ per pair like Senseglove Nova 2) as well as touch and feel prevented that.

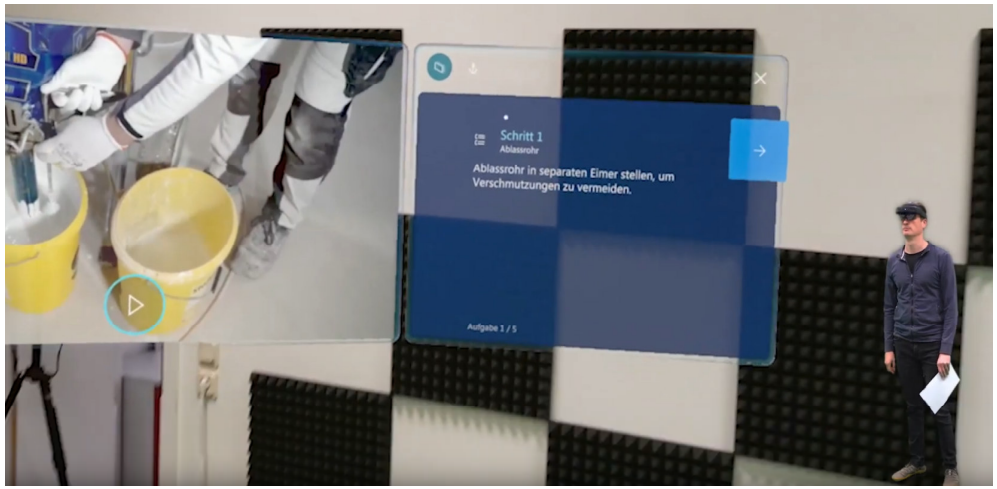
	Bricklaying: Laying a brick wall within VR	
1. Problem	Bricklayer apprentices must know how to lay a brick wall. The type and size of bricks differ. A single apprentice must have a strong understanding how to lay the brick and consider a safe and resource friendly use.	
2. Setting	The trainer gives an introduction on how to use the VR glasses and how to manoeuvre in the interactive and immersive 3D environment. The trainer provides instructions to a single apprentice to do the virtual brick laying.	
3. Solution	One learner wears the VR glasses after being instructed by the trainer on how to lay a brick wall **BEFORE** carrying it out in reality. He or she can take a brick by using the VR controller, and laying them over each other, so that a brick wall is created. The apprentices can select two types of bricks: bigger and smaller size. The use of mortar is not simulated, as the focus is on the procedure to proper lay bricks. The trainer follows him or her on the screen (work procedure) and checks the results; during the session, the trainer adjusts the performance of the learners with feedback, tips. During the use, the trainer gives feedback. After the session the trainer evaluates the performance. After that, learners lay a brick wall in reality with the support of the trainer.	 
4. Outcome	Using VR glasses allows apprentices to apply the learned bricklaying practices in a virtual and interactive environment. This supports individual learning and the subsequent transfer into real world training. This method allows to make mistakes, saves material, and provides the trainer with the opportunity to integrate digital tools in practical training.	

	Carpentry: Router use with VR and VR haptics	
1. Problem	A carpentry student must know how to use a router (is a woodworking tool used to rough, cut or hollow out an area of the front or side of a piece of wood). Routers are dangerous tools if not handled properly. The fast-spinning bit can cause injury if safety precautions and using proper technique, are not followed. Students must develop a strong understanding of safety practices, including proper hand positioning.	
2. Setting	The trainer gives an introduction on how to use the VR glasses and VR gloves and how it will be created in an immersive 3D environment where learner can see and interact with the tool in a safe environment. The trainer gives some instructions to do the performance and provides 15 minutes for the interaction.	
3. Solution	One learner wears the VR glasses and VR haptics after being instructed by the trainer on how to operate a router **BEFORE** carrying it out in reality. The haptic gloves provide feedback (vibration) like the real machine to support a real-world like experience. The trainer follows him or her on the screen (work procedure) and checks the results; during the session, the trainer adjusts the performance of the learners with feedback, tips. The rest of learners could see on the screen the performance of his/her colleague. After one learner used it, the next one uses it. During the use, the trainer gives feedback. After the session the trainer evaluates the performance. After that, learners use the router in reality with the support of the trainer.	
4. Outcome	Using VR glasses and haptics allows learners to safely practice handling a router in carpentry, solve common problems and improve their skills through repetition and feedback. It provides a risk-free environment where students can learn by doing, and they can feel the consequences of their actions through haptic feedback, making the experience more real and effective for skill-building. In addition, costs for materials are saved.	

	Parquet layer: Parquet laying with VR and VR haptics	
1. Problem	Parquet laying is an expensive and complex task. Students struggle to transfer the theoretical knowledge about how to lay a parquet in the correct order into practice as well as to select the different widths and thicknesses of the boards.	
2. Setting	The trainer gives an introduction on how to use the VR glasses and how to sue the VR haptic gloves, when navigating in an interactive digital environment to lay a parquet in 3D. During the use, trainer provides feedback. After the session the trainer evaluates the performance.	
3. Solution	One learner wears the VR glasses and VR haptic gloves after being instructed by the trainer on how to lay a parquet **BEFORE** carrying it out in reality. When a correct board is selected, the haptic gloves provide a vibration. The trainer follows him or her on the screen (work procedure) and checks the results; during the session, trainer adjust the performance of the learner with feedback, and tips. Rest of learners could see on the screen the performance of his/her colleague. After one learner used it, the next one uses it.	
4. Outcome	Using the VR glasses and VR haptic gloves gives the learner the possibility to reproduce what has been put up as an example on the screen. He/she learns that it is very important to make sure to lay the boards in the right order by following the required steps. The interactive VR environment supports the transfer of professional working steps into practice during subsequent parquet laying.	

	Painters: Airless operation within VR and VR haptics	
1. Problem	Painters' apprentices need to handle the use of technical equipment to e. g. coat a wall. An airless, which is a high-pressure machine (up to 200 bar and more), to coat undergrounds on a larger scale with paint or spatula, is in common use in painting trade. Apprentices need to develop a strong understanding of safety practices, including proper hand positioning to coat an underground.	
2. Setting	The trainer provides an introduction on how to use the VR glasses and VR haptic gloves, and how to interact with the Airless in an interactive and virtual environment to paint a wall.	
3. Solution	One painters' apprentice wears the VR glasses and the VR haptic gloves after being instructed by the trainer on how the operate the Airless **BEFORE** using it in reality. The apprentice switched on the machine in VR, selects the right spraying pressure and move with the spraying pistol closer to the virtual wall. Right action results in haptic feedback (vibration) by the VR haptic gloves. The apprentice sprays the wall with paint in the right order and the correct distance to obtain the wanted spraying pattern. During the use, the trainer gives feedback. After the session the trainer evaluates the performance. After that, the apprentice uses the airless in reality with the support of the trainer.	
4. Outcome	Using VR glasses enables the apprentices to safely operate the airless in a risk-free environment and create the wanted spraying pattern on the wanted surface. This improves the professional knowledge, by repetition and feedback. The VR use saves material and allows the trainer to demonstrate the apprentice the results of its action in a repeatable manner. The trainer obtains experience on the effect of digital media use in practical training and can provide the same experience to multiple apprentices. The apprentice can easier transfer the learnings into reality and is at the same time more motivated. This increases the retention of the professional knowledge provided.	

	Painters: Airless operation with AR	
1. Problem	Painters' apprentices typically work with an airless. It is a high-pressure machine (up to 200 bar and more), to coat undergrounds on a larger scale with paint or spatula. Apprentices need to develop a strong understanding of operating an airless. The use of an airless in training requires constant guidance by a trainer. A no-code, interactive and modern way to provide professional knowledge to is an attractive way to engage learners and carry out practical training more effectively.	
2. Setting	The trainer introduces the apprentice on how to use the Augmented Reality (AR) glasses Microsoft HoloLens 2 and the no-code Microsoft App "Guides". He created beforehand with the Guides authoring tool on his PC a digital and interactive learning path. During use an external screen is used, so that the trainer can follow the apprentices' actions in real-time.	
3. Solution	One painters' apprentice wears the AR glasses after being instructed by the trainer. The apprentice is interactively taught and guides on how to start and operate the Airless **DURING** he or she uses the Airless. After each step the apprentices carries it out directly in reality. The trainer provides real-time feedback by the live broadcast from the AR glasses to an external screen.	
4. Outcome	The AR glasses and Guides App use allow apprentices to obtain knowledge about starting and operating the Airless. This increase self-confidence and motivation. This immediate repetition of the task seen in Guides to reality foster the transfer in training practice. In addition, the trainer can easily create with texts and videos an engaging interactive learning experience. This procedure represents a more effective and more interactive way of training.	

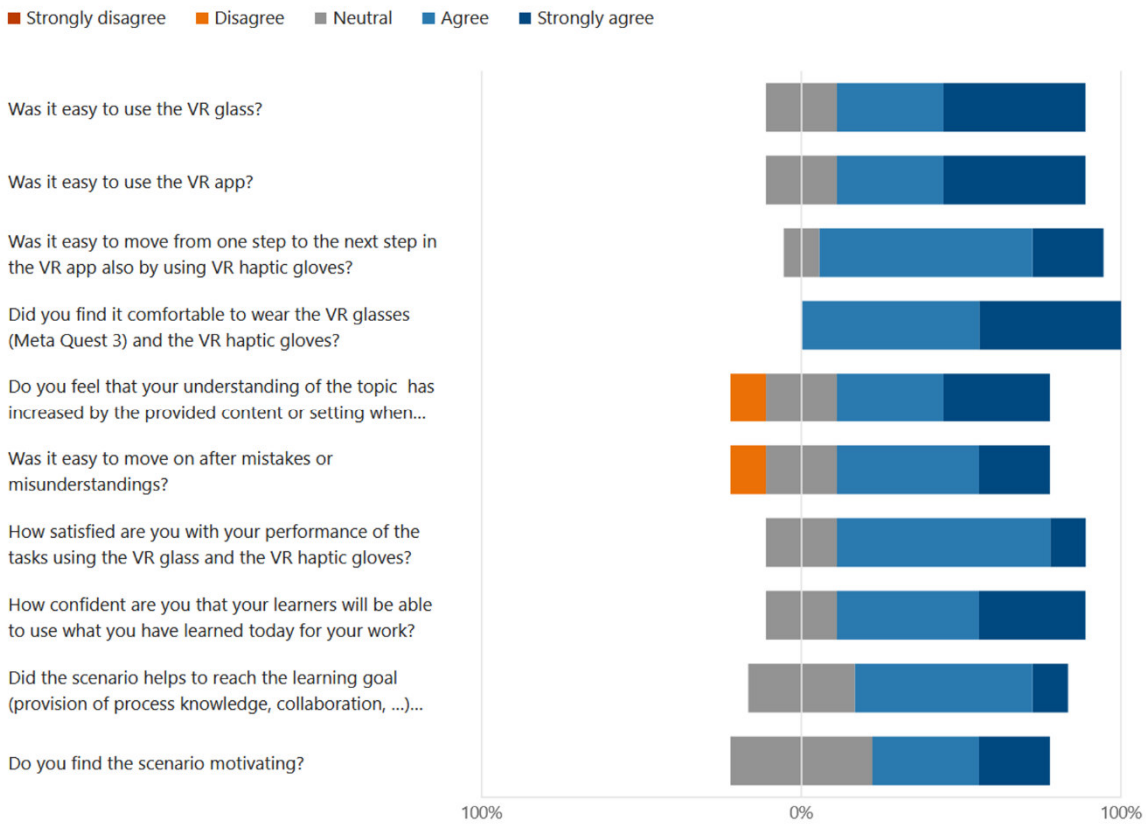


6. Evaluation

XR4CRAFTS carried out two evaluation rounds with apprentices and industry experts. 63 user feedbacks were received in total. The qualitative evaluation was carried out by a self-assessment questionnaire (Likert scale, see the appendix).

Bricklayers: 75% of the users indicated that the VR experience supports to reach the relevant learning goal and 88% think it is motivating.

Carpenters: 79% of the users found the VR and VR haptics experience useful, 70% very motivating.



Parquet Laying: 66% of the users found saw a benefit in using VR and VR haptics, and 67% found the chosen scenario especially motivating.

Painters: 76% of industry professionals perceived the VR and VR haptic use as useful to reach the learning goal. Almost the same amount (75) found the scenario motivating to use.

The positive evaluation results, especially in combination with VR haptics seem promising for further use in practical training. They also show that the scenario and technology collection as well as the pedagogic focus paid off.

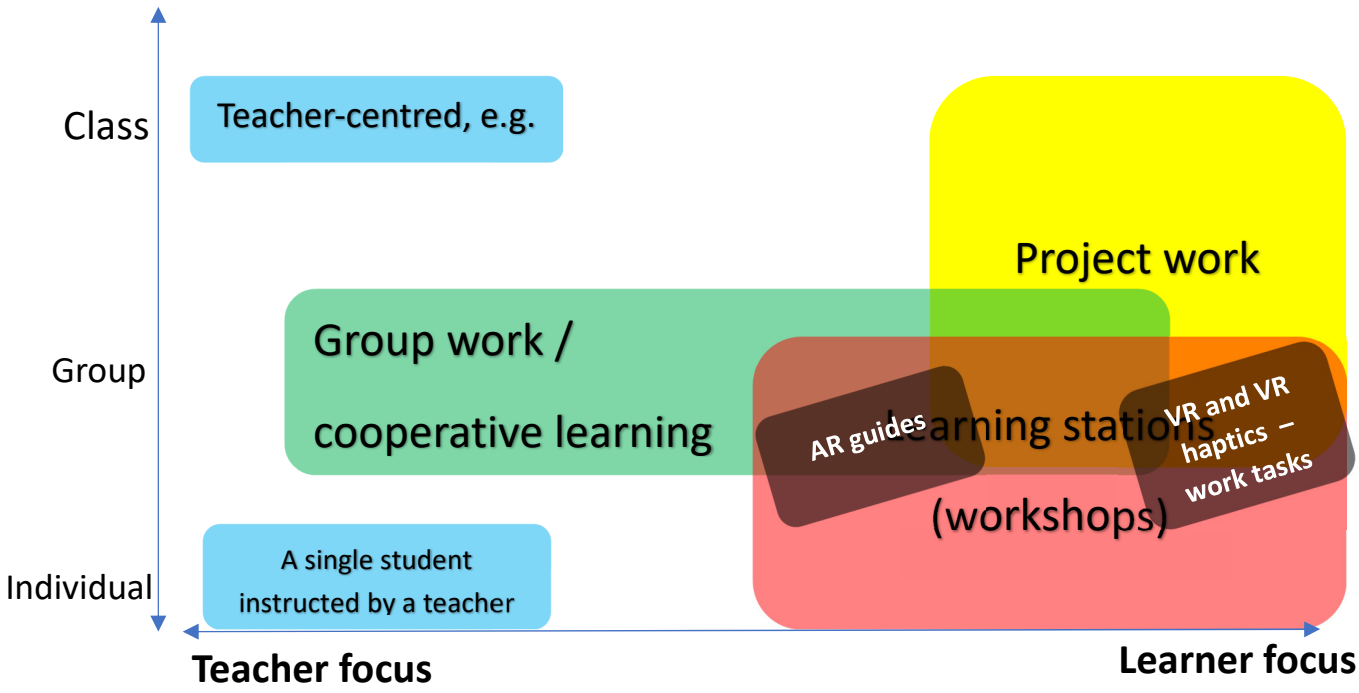
7. Some findings

All carried out forms worked and promoted rather learner-centred approaches, which ranged from **self-directed** to **expert (trainer/experienced apprentice)-accompanied** (VR and VR haptics)). The application of digital enriched or digital only scenarios supports the transition of the trainer's role: from instructor to coach. Apprentices are led towards a stronger self-organisation and a self-directed competence acquisition.

The application of AR guides does not require any programming efforts, in contrast, the VR and VR haptics environment depends completely on programming.

The testing in practical training favoured a **synchronous communication**.

The selection of the right communication and collaboration form must be framed towards the different teaching and learning form in the practical training environment.



8. Outlook

XR4CRAFTS tapped into new grounds by integrating elements of traditional and digital pedagogy with each other. Regarding the added value, we proved that AR, VR, and VR haptics are an extension of the pedagogical tools available for teaching personnel. The trainer must thoroughly ask him-/herself why, in what way and in what form these technologies can be used meaningfully.

The hardware will get more accessible and more powerful day by day. An enabling pedagogy strengthens its use towards content selection, creation, and application.

The currently limited availability of AR, VR, and VR haptics in practical training bounds the trainers to certain pedagogical teaching and learning forms. Learning stations and group works are the prerequisites to gain pedagogical expertise for extending to use to all learners at the same time.

9. Appendices

Evaluation form – VR Scenario: _____

Please cross the relevant answer.

Question	**Very much/ A lot**				**Not at all**
Was it easy to use the VR glass?					
Was it easy to use the VR app?					
Was it easy to move from one step to the next step in the VR app?					
Did you find it comfortable to wear the VR glasses (Meta Quest 3)?					
Do you feel that your understanding of the topic has increased by the provided content or setting?					
Was it easy to move on after mistakes or misunderstandings?					
How satisfied are you with your performance of the tasks using the VR glass?					
How confident are you that your learners will be able to use what you have learned today for your work?					
Did the scenario helps to reach the learning goal (provision of process knowledge, collaboration, …) better?					
Do you find the scenario motivating?					

Comments (optional):

Evaluation form – VR+ VR haptics scenario: _____

Please cross the relevant answer.

Question	**Very much/ A lot**				**Not at all**
Was it easy to use the VR glass?					
Was it easy to use the VR app?					
Was it easy to move from one step to the next step in the VR app also by using VR haptic gloves?					
Did you find it comfortable to wear the VR glasses (Meta Quest 3) and the VR haptic gloves?					
Do you feel that your understanding of the topic has increased by the provided content or setting when using VR haptic gloves?					
Was it easy to move on after mistakes or misunderstandings?					
How satisfied are you with your performance of the tasks using the VR glass and the VR haptic gloves?					
How confident are you that your learners will be able to use what you have learned today for your work?					
Did the scenario helps to reach the learning goal (provision of process knowledge, collaboration, …) better?					
Do you find the scenario motivating?					

Comments (optional):

Satisfactionary form – AR Guides scenario: _____

Please cross the relevant answer.

Question	Very much/ A lot				Not at all
Was it easy to use the AR headset?					
Was it easy to use the AR app?					
Was it easy to move from one step to the next step in the AR app?					
Did you find it comfortable to wear the AR glasses (Microsoft HoloLens 2)?					
Do you feel that your understanding of the topic has increased by the provided content or setting when using AR glasses gloves?					
Was it easy to move on after mistakes or misunderstandings?					
How satisfied are you with your performance of the tasks using the AR glass?					
How confident are you that your learners will be able to use what you have learned today for your work?					
Did the scenario helps to reach the learning goal (provision of process knowledge, collaboration, …) better?					
Do you find the scenario motivating?					

Comments (optional):