PEDAGOGICAL GUIDELINES

FIGHTARs

Written by Jens Hofmann on behalf of the FIGHTARs-Partnership.

The FIGHTARS partners are:

- SPSCH - Upper Secondary School of Chemistry Pardubice (CZ),
- Estonian Academy of Security Sciences (EE),
- Fire Fighters Training School (LT),
- University of Zilina (SK),
- SCP Academy – School of Certified Professionals (CY),
- SBG Dresden – Saxon Training Company for chemical and environmental professions (DE).

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Contents

1. Introduction

The technological possibilities applicable in training have increased exponentially and are expected to do so in the future. However, it is unclear what technologies are already stable and easy to use for firefighters training.

Education personnel are always looking for efficient and effective education that meets the wishes of learners and society, psychological and pedagogical insights using the latest technological possibilities. The FIGHTARs project involved professional firefighters and programmers to answer questions like: How can Augmented Reality (AR) glasses be implemented in firefighters and incident commanders training? What training cases should be created? What kind of digital skills are needed to use AR-based learning materials?

The FIGHTARs project mission is:

Train firefighters and incident commanders today to prepare them for tomorrow's challenges by the tailor-made support of trainers and learners through educational innovations.

Education is geared towards a future in which teaching personnel and technology work together to provide learners the knowledge and skills necessary for carrying out professional tasks. A today's life without technology is unthinkable. Technology by itself influences how we live, work, and learn. Trainers play an essential role for a meaningful application of relevant technology which results in better learning results and higher motivated learners. These guidelines are for firefighter trainer to know about and to implement modern, digital media in training. In addition, they are also aimed for school administration to realize the support of trainers' needs.

The use of modern media like Augmented Reality (AR)and 360° in firefighter's training is new ground. The fields of application are manifold. In FIGHTARs we focussed on the following topics:

- Rescue works (e. g. technical aspects of traffic accidents with electrical car)
- Handling hazardous substance exposure
- First aid in traffic accidents

2. Hard and Software

Augmented Reality is the enrichment of the visible reality with computer generated, interactive holograms for purposes like guidance and explanation of non-visible processes. To see holograms, specialised technology, like smart glasses (AR glasses), smartphones or tablets are necessary. The use of smart glasses allows that both hands are free during live training, when interacting with the glasses

360° video enables users to "dive into" a digital generated environment. It is used for the documentation of real environments and for the orientation of users in space. It represents a "simpler" form of Virtual Reality (therefore VR). Interactivity is created by the integration of buttons for accessing further information, such as videos, 3D objects, weblinks etc.

Figure 1. AR (left, marketing video) and VR (right, booth use) cases for existing applications

The development of smart glasses hard- and software is dynamic. The technology itself is not a new one. Current limitations are the price tag of the devices, partly the stability as well as resources spend to create tailor-made content. 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 specific working and learning environments such as for firefighting training.

Decisive factors for buying smart glasses are:

- Field of view
- Control options
- Refresh rate (for visualisation stability and latency)
- Weight
- Battery duration
- Operating System
- Price
- Perceived easiness to create and use own or tailor-made training content

During the FIGHTARs project we tested the Microsoft HoloLens 2 (AR glass) in classroom and live-training to overcome these limitation (see Appendix 8).

Table 1 provided an overview of currently available Augmented Reality and Virtual Reality glasses as well as 360° cameras.

Table 1: AR and VR headsets & 360° cameras (selection)

	Microsoft HoloLens 2 (AR)	Vuzix Blade (AR)	Oculus Quest 2 (VR)	HTC Vive Pro (VR)	Varjo XR-3 (VR)	Insta 360 One X	Ricoh Theta Z1	GoPro Fusion
								
Standalone	✓	✓	✓	✗	✗	✓	✓	✓
Field of view (horizontal)	43°	19°	89°	120°	115°	150°	360°	220°
Control	Gestures + voice	Touch pad	Controllers	Controllers	Controllers	Buttons	Buttons	Buttons
Refresh rate	60Hz	n/a	120Hz	90Hz	90Hz	n/a	n/a	n/a
Weight	566 g	93.6 g	503 g	1 018 g	980 g (with headband)	149 g	182 g	220 g
Battery	2-3hrs	1-2hrs	2-3hrs	Via PC	Via PC	80 min	130 min	75 min
Operating system (compatibility)					n/a			
Price	3 800 €	1 200 €	350 €	660 €	1 495 €	490 €	1 000 €	250 €

Note: Selected Augmented Reality (AR) and Virtual Reality (VR) glasses are presented as they enable to see 360° videos what a 360° camera record.

The application of Augmented Reality (preferably AR glasses, but also applicable to smartphones and tablets) is suitable for:

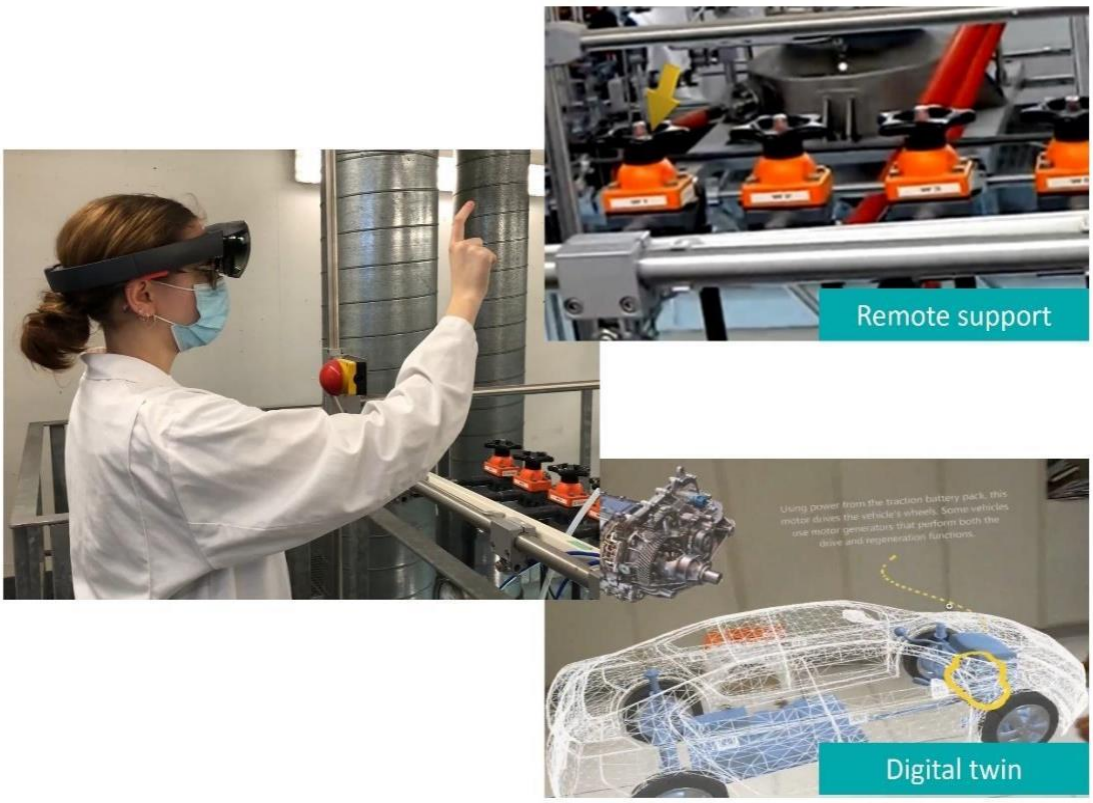


Figure 2. Augmented Reality options

AR - Remote support (Remote Training): The audio-visual guidance of the expert to the learner, who wears the AR glasses (e. g. Microsoft HoloLens 2). The expert, a trainer or an experienced professional can say open a valve and annotate the valve with a digital generated hologram in the shape of an arrow. The required hard- software involves:

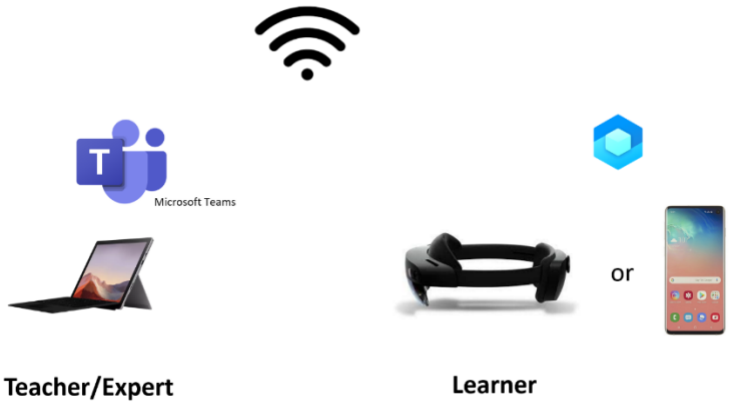


Figure 3. Augmented Reality Remote Support hard- and software

AR - Digital Twin: Interactive digital twins (“digital 3D copies”) of objects enable firefighters to virtually interact with a e. g. am electrical car visualisation. The relevant hard- and software needed is AR glasses and app to insert the model (see figure 4):

Figure 4. Augmented Reality Digital Twin technology needs

These guidelines will use terms like:

Lesson plan – A detailed description of the course of instruction for a lesson.

Scenario – It describes what learners should do with support of the trainer, the technologies available and the possible learning forms.

LMS – Abbreviation for Learning Management System. A LMS enables to provision of learning content as e-learning modules within a webpage.

3. Survey based training needs of firefighters to create to FIGHTARs app

To assess existing and future training demands an online survey was carried among firefighter stations and firefighters training organisation in the Czech Republic, in Estonia, in Lithuania and in the Slovak Republic in April 2021. Almost half of the 63 respondents have already experience with Virtual Reality, but only around 10% worked before with Augmented Reality glasses or applications (see figure 5).

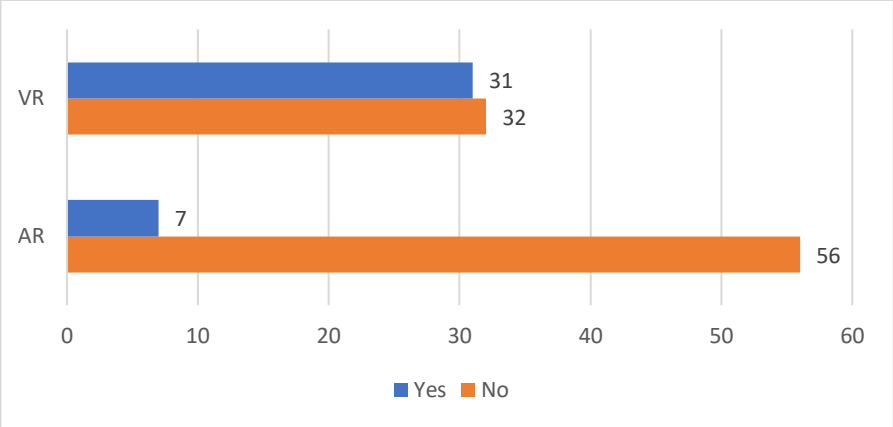


Figure 5. Experience with Augmented Reality (AR) and Virtual Reality (VR) in training

The dominating topic is the provision of technical and procedural skills by the means of interacting with a digital object or a digitally enriched real object. Augmented Reality is seen as suitable for the fields of extinguishing burning cars, such as electrical or hybrid cars, and cutting a crashed car open to rescue a person. Also, the training of procedures, when dealing with different hazardous substances is seen useful. In contrast, Virtual Reality and 360° video is seen useful in training when simulating very dangerous situations, and training teamwork and tactical skills (see figure 6).

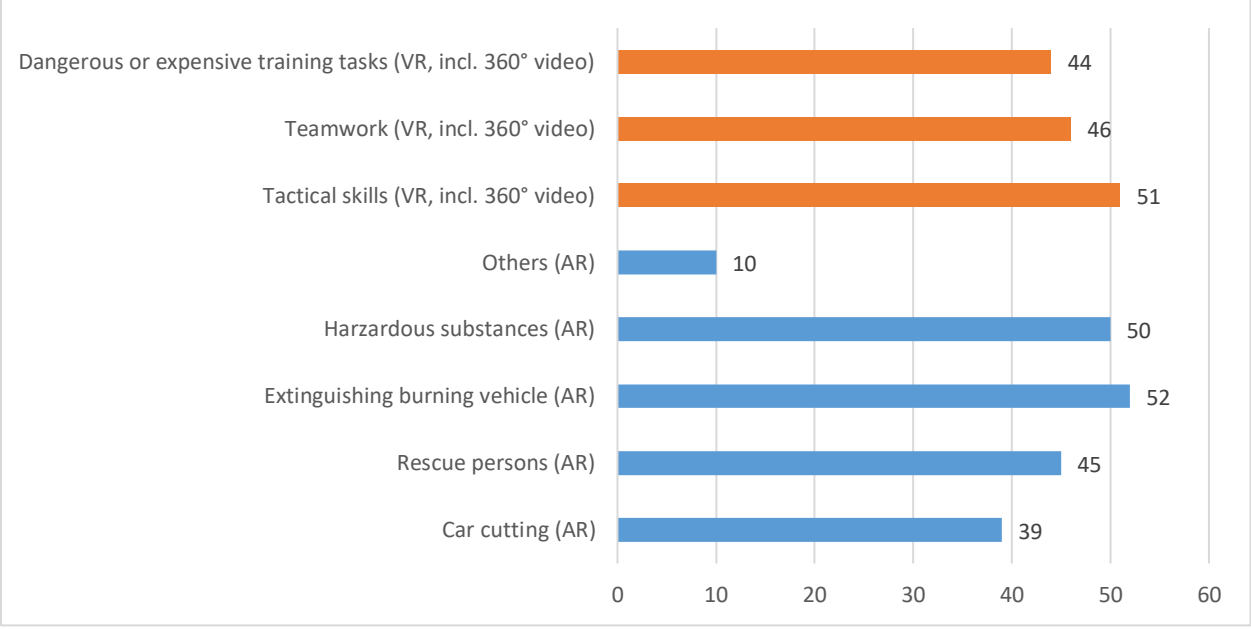


Figure 6. Preferred learning scenarios with Augmented Reality (AR) and Virtual Reality (VR)

The interest among learners and professional firefighters showed, that 80% are interested in AR and VR applied in different kind of training formats. 360° video use found by 75% suitable.

The largest approval obtained a mixture of on- and offline measures with almost 80% followed by practical workshops with around 60%. Pure online sessions are seen only by around 50% useful (see figure 7).

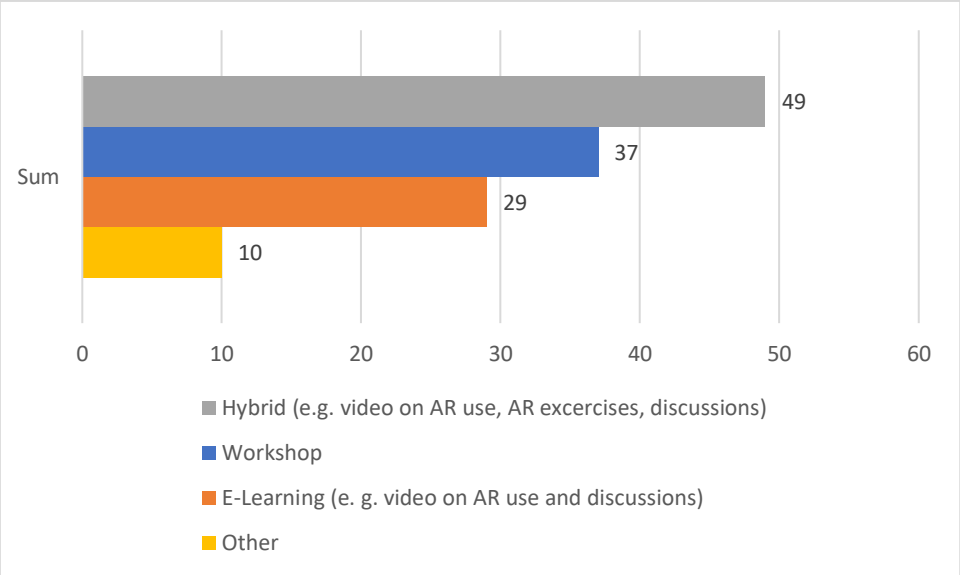


Figure 7. Preferred way of training provision

FIGHTARs focusses on the pedagogically sound application of Augmented Reality, 360° video and learning video application in firefighters training. The survey results correspond with relevant and applicable learning theories.

4. Learning and teaching using AR and 360° videos

The use of modern media into firefighters training must be integrative and complementary in the first place to be applicable. Pedagogical questions of modern media use are key. The FIGHTARs project asks:

How can we ensure a pedagogical added value of the teaching and learning scenarios when applying AR and 360° video in firefighters training?

Existing learning theories provide frameworks and models to develop suitable approaches for technology enriched theoretical and practical training.

Firefighters' training is currently a mix online, classroom and live-training. [1] In the classroom the provision of theoretical knowledge (regulations, chemistry etc.) is key. During live training the handling of equipment, experience with heat, time pressure etc. is key to gain the necessary knowledge and skills. Classroom and live training have already proven methods for development, carrying out and assessment. [1]. A live training can be resource-intensive (training personnel, specialized facilities, equipment, and well-planned scenarios) and hazardous for trainees (real temperatures, risk to fall) and environment (smoke, chemical wastes etc).

The use of AR and 360° will not replace classroom or live or their evaluation [2], but it has the potential to enrich both forms technically and pedagogically.

To successfully implement a new technology within practical training a four-step approach is recommended.

Step 1: Decision on sound combination of work knowledge, appropriate learning approaches technology and content?

A trainer and trainee need integrated knowledge of following areas:

- Working Knowledge– What practical competences are necessary to master a task and how AR and 360° video support learning?
- Content Knowledge - What lesson content does he or she want to offer with AR and 360° video?
- Andragogy Knowledge or Adult learning approaches – What are appropriate ways to support and facilitate teaching and learning when using AR and 360° video?
- Technology Knowledge- How should AR and 360° video used to achieve the learning goals?

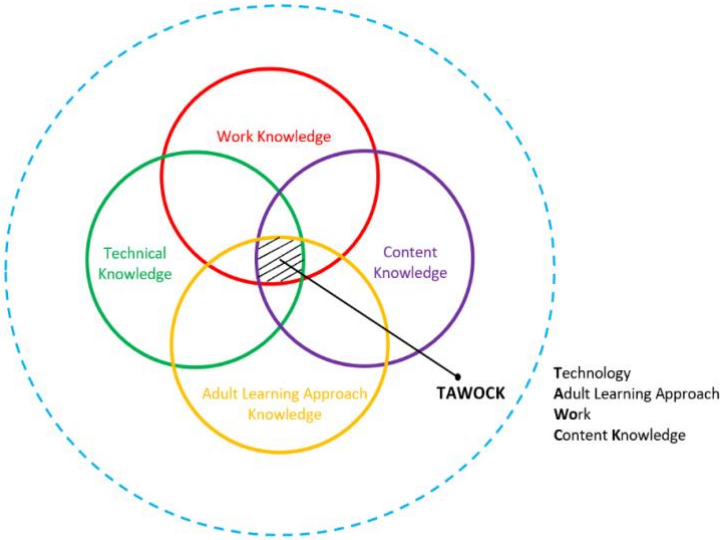


Figure 8. TAWOCK model elements [13]

"TAWOCK" is a conceptional model for the relationships between work areas, content delivered, technology needs and learning approaches adapted. It provides a framework for planning and execution of classroom training and live training. It results in a technology-enriched and pedagogical effective provision of learning contents.

STEP 2: Decision on what are the learning objectives?

The integration of AR and 360° video 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 is for[1]:

a) AR rather on activities such as "**clarify**", "**carry out**", "**integrate**" or "**judge**".
b) 360° video rather on activities such as "**recognize**", "**recall**", "**summarize**" or "**classify**".

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

By the completion of the classroom and/or live training the impact on emergency preparedness must be evaluated.

STEP 3: Evaluation of a training program

To evaluate learning sequences a four-step approach (see below and Appendix 3) can be applied. The single stages are independent from a learning perspective, e. g. positive feedback does not necessarily translate to effective learning, which in turn does not always lead to improved practice in the work setting.

[1] See appendix 1 – clarification of learning objectives according to Blooms taxonomy.

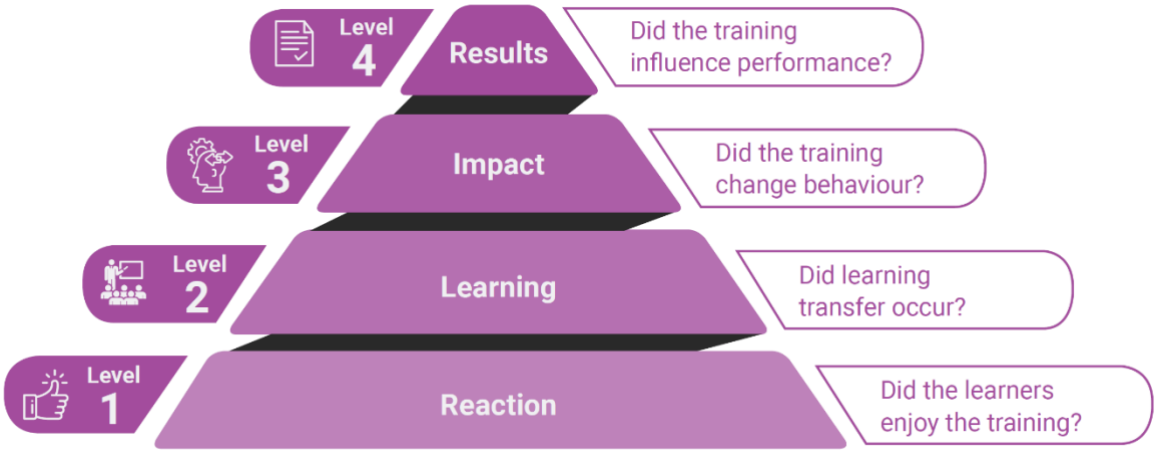


Figure 9. Kirkpatrick training model

There are different ways to evaluate different levels of training:

Level 1 – Collection of subjective information by end of session questionnaires

Level 2 – Observations by trainers on gained proficiency level, time to complete a task, number of errors, number of questions asked by the learners, skills test etc

Level 3 – Formal or informal assessment with measures built in for quality and comparability (e. g. examination situation after course in new situation)

Level 4 – Work based formal assessment of competence or practice, carried out in the workplace, or using evidence from work activity. An alternative is the written or verbal feedback from learners' supervisors.

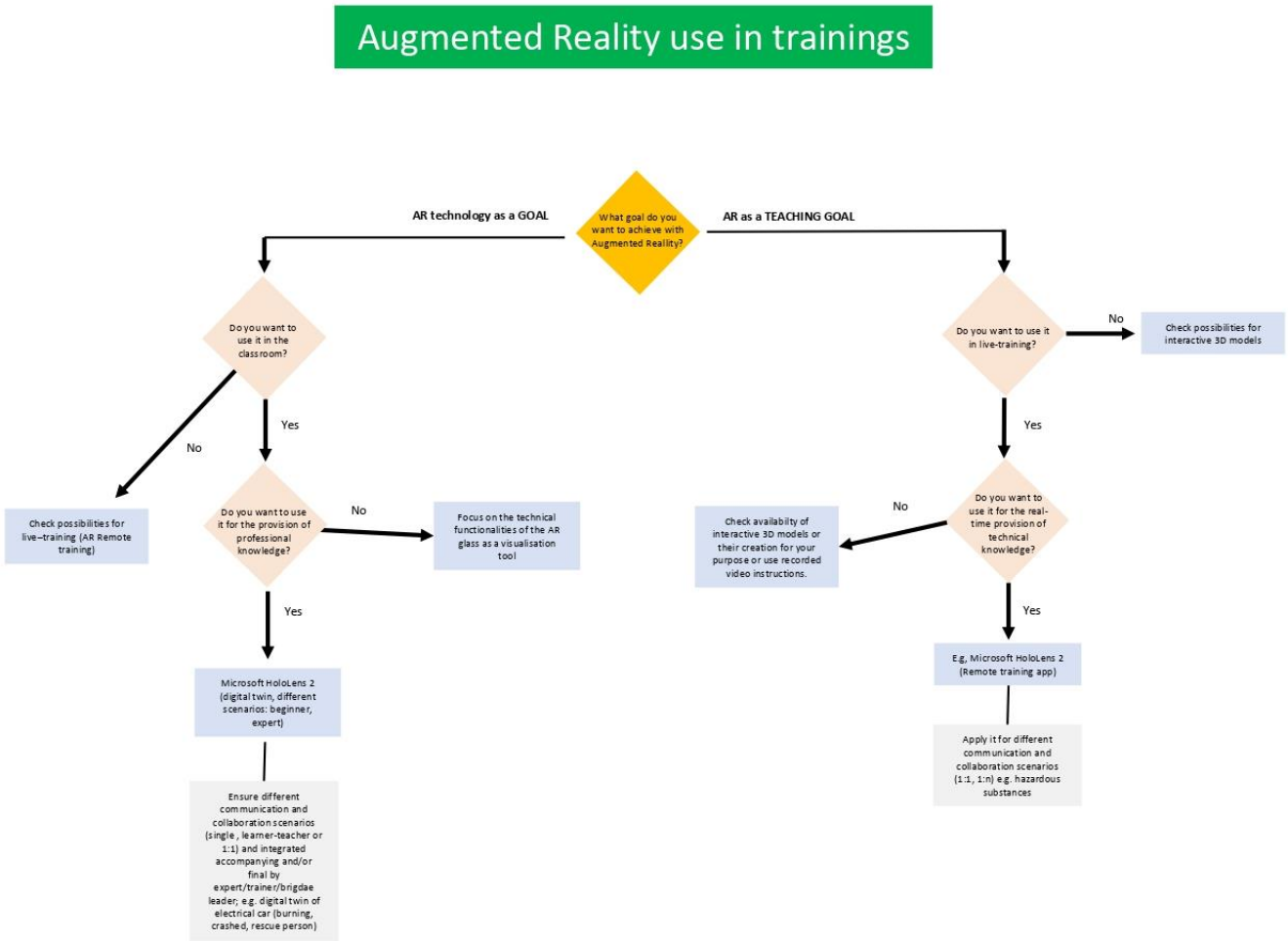
5. Technology enriched learning scenario provision

The application of AR, 360° video and e-learning modules videos **enrich** and not replace learning in the classroom, or live trainings. AR, 360° video and e-learning modules are designed to increase the firefighter's preparedness for live trainings by the provision of professional knowledge e. g. on how to handle the equipment.

The use of AR and 360° is favourable during classroom trainings. Learning videos can prepare or accompany classroom training. The application of e. g. AR (remote training) during live trainings must be tested. The application of AR on the way to an incident scene is thinkable scenario.

The application of AR and 360° can be tied to a single scenario or it can be used more versatile. The integration of an interactive visualisation (digital twin) of a crashed car is specific, in contrast to the use of AR Remote support (see page 7) for audio-visual support when dealing with a real car body in training.

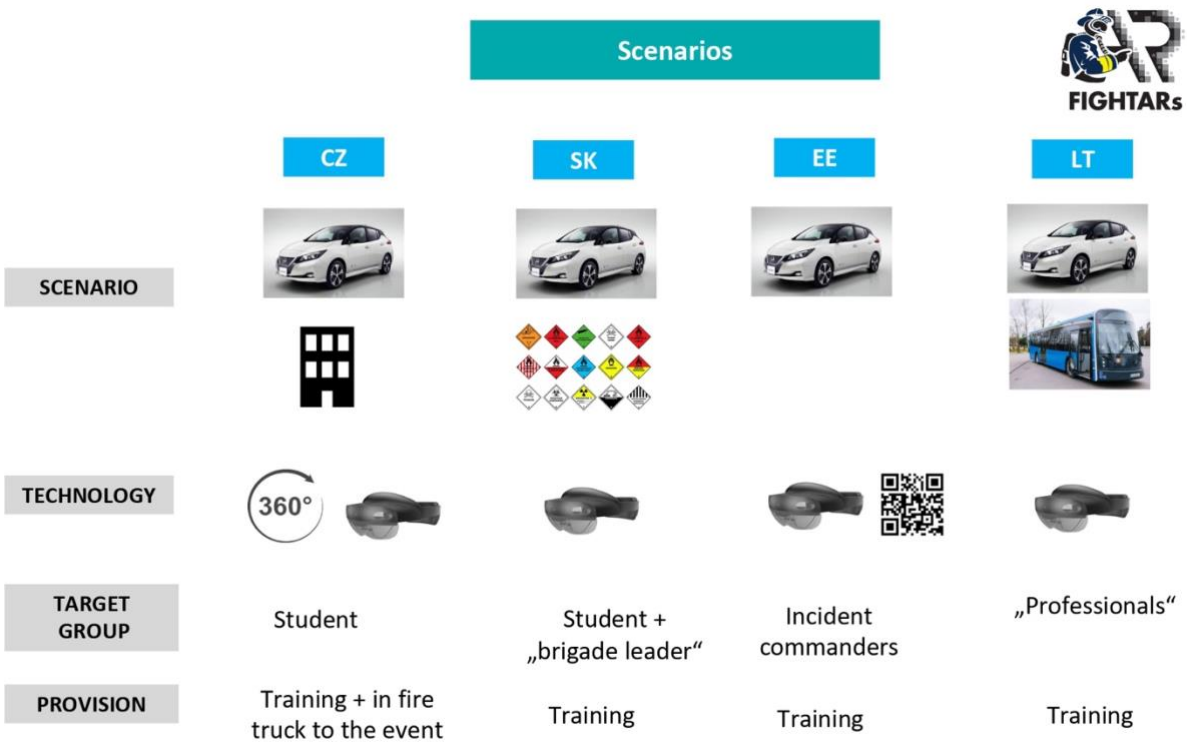
For a pedagogical sound use in training specific **learning scenarios** are needed. Scenario-based learning involves real-world scenarios to create an immersive and relatable learning experience for learners. Learners are assigned to specific roles and face different problem situations. Herewith they obtain the demanded set of knowledge, skills, and competences. This way of training specifies roles, activities, resources, and relevant tools.

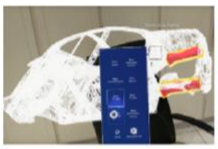


STEP 1: What educational challenge or problem AR and 360° video should solve in the four firefighter training institutions?

Provision of technical skills over distance (different hazards and car types)	Better collaboration	Database access on the way to accident
	Prep training (H&S)	
Knowledge provision	Train dangerous situation upfront (elect. car)	

STEP 2: Fields of application



SCENARIO				
	Car: Cutting	*Hazardous substances*	*First aid*	*Electrical car: deactivation battery*
TECHNOLOGY				
PROVISION	Training + in fire truck to the event	Training	Training	Training

The selection of applications was carried out by internal and by external experts (survey). AR is seen suitable for the deactivation of the battery pack e. g. for extinguishing burning cars (especially electrical car), cutting a crashed car open to rescue (injured) passengers. In addition, the handling of hazardous substances is a must. During training different communication and collaboration scenarios (single person, in group) will emerge to train especially teamwork skills.

STEP 3: Scenario development (combining STEPS 1+2)

The technology choices are intended to **enrich or augment** classroom and potentially live trainings. It is important to define for what working steps on which scenario and which way of provision (**TAWOCK[2] model**) AR and 360° video is used. AR should focus preferably on activities like to carry out or judge something, in contrast to 360° videos where the recognition, recalling and summarizing of knowledge is key.

To develop any learning scenario first learning outcomes for learners' need to be phrased (see chapter 4).

Below are six TAWOCK-oriented lesson plans:

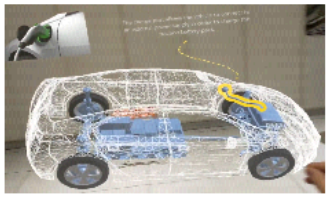
a) Deactivation battery pack of an electrical car (classroom training)
b) Dealing with hazardous substances (classroom training)
c) First aid in case of a traffic accident (classroom / live training
d) Extinguishing burning electrical car (AR digital twin - classroom training)
e) Hazardous substances (oil spill) (AR remote training - classroom/live training)
f) Handling indoor fires/indoor navigation (360° video - classroom training)

[2] See page 12.

a) Deactivation battery pack of an electrical car (classroom training)

SCENARIO DEACTIVATION BATTERY ELECTRICAL CAR (AR DIGITAL TWIN) [CLASSROOM TRAINING]

E-car



LEARNING CONTENT PHASE	WORKING STEPS (LEARNING ACTIVITIES)	TECHNOLOGY	COMMUNICATION & COLLABORATION	TEACHER ACTIVITIES
Analysis/Orientation (xx min) ("Clarify")	* Arrival to (virtual) incident scene * Analysis car type	*AR visualisation e-car *AR digital twin in set environment *AR digital twin with views battery package location etc.	*Learner-teacher (1:1), brigade leader (teacher) briefs on scene with latest information * Teacher follows over screen	* Verbal presentation scenario * Introduction AR glasses
Execution (xx min) ("Carry out")	* Selection parts and deactivation battery	*AR digital twin * AR digital twin with visible and audio signs of fire, high voltage, ...)	*Learner-teacher (1:1), teacher verbal support	*Verbal guidance, if needed
Assessment (xx min) ("Judge")	*Deactivation battery(time)	*Integrated quiz to follow measures	*1:1 evaluation performance in dialogue	* Carrying out dicussion/dialog

b) Dealing with hazardous substances (classroom training)

SCENARIO	HAZARDOUS SUBSTANCES (AR Digital twin)		[CLASSROOM TRAINING]

LEARNING CONTENT PHASE	WORKING STEPS (LEARNING ACTIVITIES)	TECHNOLOGY	COMMUNICATION & COLLABORATION	TEACHER ACTIVITIES
Analysis/Orientation (xx min) ("Clarify")	* Arrival to (virtual) incident scene * Analysis if persons in danger * Analysis environment pollution * Determination hazardous substance(s)	*AR digital twin of incident scene	*Learner-teacher (brigade leader) (1:1) by screensharing	* Verbal presentation scenario * Introduction AR glasses * Audio-visual instruction + support
Execution (xx min) ("Carry out")	Tell planned actions (chemical specific): * Tell hazardous substance and resulting measures like: *Collection of oil-water-mixture by various equipment * Temporary storage of mixture in tanks, re-serviors *Water treatment (case: major accident, low concentration of oil-water-mixture) *Disposal of pollutants (by specialists)	*AR digital twin of incident scene	*Learner-teacher (brigade leader) (1:1) by screensharing	* Self guided with visual support by trainer (sees actions: external screen)
Assessment (xx min) ("Judge")	*Actions suggested	*Discussion with trainer during observation and planning actions according to chemical	*1:1 performance evaluation	* Carrying out dicussion/dialog

c) First aid in case of a traffic accident (classroom / live training)

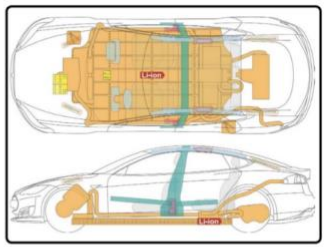
SCENARIO	First aid (AR avatars of injured persons)		[CLASSROOM/LIVE-TRAINING TRAINING]

LEARNING CONTENT PHASE	WORKING STEPS (LEARNING ACTIVITIES)	TECHNOLOGY	COMMUNICATION & COLLABORATION	TEACHER ACTIVITIES
Analysis/Orientation (xx min) ("Clarify")	* Arrival to incident scene	*QR Code triggered AR digital twin person with different injuries with access to an Learning Management System for consulation and carry out exams	*Individual learning with possibiliy to screenshare view	* Verbal presentation scenario * Introduction AR glasses and QR Code use
Execution (xx min) ("Carry out")	* Detect injuries: Catastrophic bleeding (yes/no) * Plan further possible measures: checking breathing and possible spinal injuries	*QR Code triggered AR digital twin person with different injuries with access to an Learning Management System for consulation and carry out exams	*Individual learning with possibiliy to screenshare view	* Self guided with visual support by trainer (sees actions: external screen)
Assessment (xx min) ("Judge")	*Actions suggested	*Discussion with trainer	* Performance evaluation	* Carrying out dicussion/dialog

d) Extinguishing burning electrical car (AR digital twin - classroom training)

SCENARIO	EXTINGUISHING BURNING ELECTRICAL CAR (AR DIGITAL TWIN)	[CLASSROOM TRAINING]

TESLA MODEL S



LEARNING CONTENT PHASE	WORKING STEPS (LEARNING ACTIVITIES)	TECHNOLOGY	COMMUNICATION & COLLABORATION	TEACHER ACTIVITIES
Analysis/Orientation (xx min) ("Clarify")	* Arrival to (virtual) incident scene * Analysis persons in danger * Analysis environment (close buildings etc.) * Analysis car type (e.g. Tesla Model S)	*Video *AR visualisation: Person in car *AR digital twin in set environment *AR digital twin with views battery package location etc.	*Learner-teacher (1:1), brigade leader (teacher) briefs on scene with latest information * Teacher follows over screen	* Verbal presentation scenario * Introduction AR glasses
Execution (xx min) ("Carry out")	*Selection extinguishing agent (e.g. water < 10m³, small fire ABC fire extinguisher) *Vehicle extinguishing (standard tactics+ equipment, re-ignition of high voltaage battery by sound of clicking, then white smoke and/or sparks + visible flames) *Ensure distance of min. 15m from other cars or buildings * Cooling burned battery for 24hrs+ to prevent re-ignition	*AR digital twin with proximity tracker (1m = 10 cm in visualation to create spatial under-standing) * AR digital twin with visible and audio signs of fire, high voltage, ...) *AR digital twin options cooling (e. g. water diving)	*Learner-teacher (1:1), teacher verbal support	*Verbal guidance, if needed
Assessment (xx min) ("Judge")	*Extinguishing burning car (time)	*Integrated quiz to follow measures	*1:1 evaluation performance in dialogue	* Carrying out dicussion/dialog

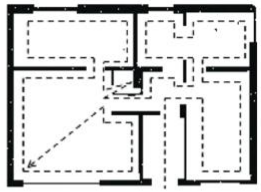
e) Hazardous substances (oil spill) (AR remote training - classroom/live training

SCENARIO	HAZARDOUS SUBSTANCES (OIL SPILL) (AR REMOTE TRAINING)	[CLASSROOM/LIVE-TRAINING TRAINING]

LEARNING CONTENT PHASE	WORKING STEPS (LEARNING ACTIVITIES)	TECHNOLOGY	COMMUNICATION & COLLABORATION	TEACHER ACTIVITIES
Analysis/Orientation (xx min) ("Clarify")	* Arrival to (virtual) incident scene * Analysis if persons in danger * Analysis environment pollution * Determination hazrdous substance(s)	*AR Remote training Stream (no programming) *AR Remote training Stream (no programming) *AR Remote training Stream (no programming) *AR Remote training Stream (no programming)	*Learner-teacher (brigade leader) (1:1)	* Verbal presentation scenario * Introduction AR glasses * Audio-visual instruction + support
Execution (xx min) ("Carry out")	*Use of spill containment (stop entering larger bodies of water) by bonnet barriers, sorbents *Collection of oil-water-mixture by various equipment * Temporary storage of mixture in tanks, re-serviors *Water treatment (case: major accident, low concentration of oil-water-mixture) *Disposal of pollutants (by specialists)	*AR Remote training Stream (no programming) *AR Remote training Stream (no programming) *AR Remote training Stream (no programming) *AR Remote training Stream (no programming) *AR Remote training Stream (no programming)	*Learner-teacher (brigade leader) (1:1)	* Audio-visual instruction + support
Assessment (xx min) ("Judge")	*Collection of pollutants (time, ...))	*Discussion on recorded remote-training session between learner and trainer	*1:1 performance evaluation	* Carrying out dicussion/dialog

f) Handling indoor fires/indoor navigation (360° video - classroom training

SCENARIO HANDLING INDOOR FIRES/INDOOR NAVIGATION (360° video) [CLASSROOM TRAINING]



LEARNING CONTENT PHASE	WORKING STEPS (LEARNING ACTIVITIES)	TECHNOLOGY	COMMUNICATION & COLLABORATION	TEACHER ACTIVITIES
Analysis/Orientation (xx min) ("Recognize")	* Arrival to (360°) incident scene * Analysis persons in danger and neighboring buildings affected * Analysis kind of fire (where + color) * Analysis water hydrants location and hose line lenght	*360° video *360° video *360° video *360° video	Single learner	* Verbal presentation scenario * Introduction 360° video use
Execution (xx min) ("Recall")	* Selection extinguishing agent (e.g. water) * Analysis building indoor (e.g. door hot, door opens in- or outside) * Deciding on movement combustion hearth * Searching the combustion hearth * Building mapping * Rescue (of persons, animals)	360° video *360° video + quiz on entering flat options *360° video + quiz on strategy reaching to fire *360° video + quiz on strategy searching fire *360° video on mapping options (search) *360° video on rescue operation	Single learner	*Support if requested
Assessment (xx min) ("summarize")	*Extinguish combustion hearth, rescuing people, animals (time, ...)	*Integrated quiz to follow measures	*Evaluation of quiz results and overall performance by trainer	* Carrying out dicussion/dialog

The FIGHTARs App is connected to the learning management system (LMS) of the project webpage (http://fight-ar.com/). This enables the update of contents in the LMS.

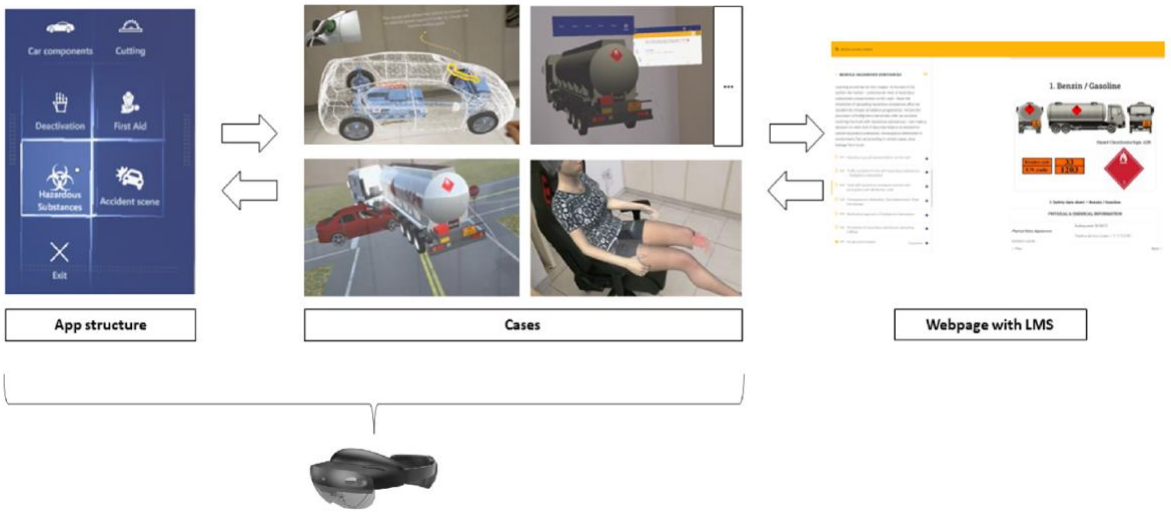


Figure 10. FIGHTARs app cases and LMS integration

6. Learning labs for immersive training in firefighting

A “Learning Lab” is a means aimed at inspiring and guiding teachers, trainers, and firefighters’ students to implement ICT-rich education at their own school or training institute.

A “Learning Lab” is not only a physical place where firefighter teachers and trainers gain knowledge and experience about technological needs and support but also a space to test ready-made materials like the FIGHTARs AR app and LMS.

a) Learning labs: Development plan

The plan should incorporate

- a *vision* (“How education can influence to world of tomorrow?”),
- a *strategy* (“How we will achieve it”?) and
- a *mission* (“What are our core values?”, “How do we want to deal with learners and employees?”)

Within the FIGHTARs project we define the strategy as to set up learning labs. This involves the following steps:

- **Understand** (What is known? What does fit in the mission and vision of planned learning labs? For whom, why, what, and how the learning labs are developed? (incl. educational questions)
- **Explore** (What scenarios and training settings are suitable? Which digital prototypes should be built and tested?)
- **Materialize** (What the user liked? What did they not like? What should be altered? How to bring the final product to more users?)

b) Decision making

Key is to make explicit choices on the professionalisation of teachers/trainers ICT skills by the school board. Options are:

- information meetings,
- short courses and trainings,
- coaching and peer review,
- participation in a network and
- external trainings.

c) Professionalisation of teachers/trainers (see figure 11)

Figure 11. Flow chart professionalisation of teaching personnel in 3 steps

d) Content development for trainings

The enrichment of existing trainings with modern digital media is aimed, instead of creating new qualification offers in the first place. Key is the description of the specific educational problem or challenge where the new technology or technologies can help with.

For training purposes, for the handling with a crashed car (no electrical car) learning videos (preferably classroom training) as well as Augmented Reality Remote Support (live trainings) are applicable separately or in combination. Both options do not require any software programming capabilities from the trainer in the content creation phase.

The software programming of an interactive digital twin would only make sense for training dangerous or expensive scenarios, like the deactivation of the battery pack of a burning electrical car. This requires from the trainer to contact a software programmer or use existing visualisations.

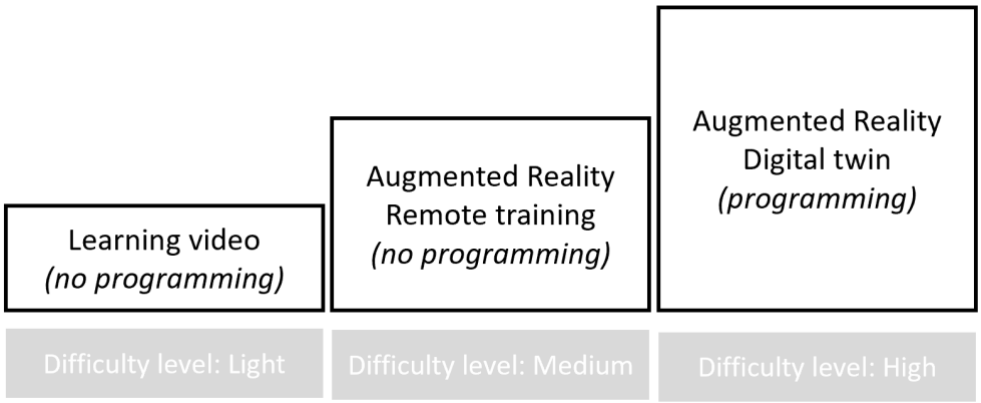


Figure 12. Visualisation "staircase" (media creation)

7. Recommendations

The FIGHTARs project brings Augmented Reality and 360° video to firefighters training in order to support spatial learning and increase situational awareness by the provision of especially technical knowledge. AR and 360° video do not replace but enrich existing classroom and live trainings by focussing on the pedagogical added value (pedagogy > technology). They are expected to be strongly complementary to existing experiences with Virtual Reality in firefighters training.

The preferred scenarios (deactivation of electrical car battery, cutting a car open after a crash, first aid and handling hazardous substances) are possible to implement. For a pedagogical sound-application the TAWOCK (Technology-Adult Learning–Work & Content Knowledge) model is suitable. The seamless implementation will enrich the currently rather general published experiences about AR and 360° video use in firefighters training with real use cases. The potential is there to also test the feasibility of e. g. AR remote training during selected live trainings.

A structured way of facilitation for integrating AR and 360° in theoretical and live training is needed. The learnings among the four planned centres of immersive firefighters training shall be shared over different means of communication to identify best practices, which are transferable and therefore scalable. This ensures a further use of AR and 360° in firefighters training.

APPENDICES

APPENDIX 1: Formulation of learning objectives (Bloom)

APPENDIX 2: Evaluation

LEARNER FEEDBACK (CLASSROOM TRAINING AND LIVE TRAINING) on tool test and learning methods applied

Scaled questions (suggest 5-point scale).

Question	Yes/Very much/ A lot				No/ Not at all
Did you find the session/course well organised and structured?					
Did you find the process straightforward to follow?					
Do you feel that your understanding of the topic has increased?					
How satisfied are you with your performance of the tasks?					
How confident are you that you can use what you have learned at work/in an independent project?					
Did you find it easy to recover from mistakes or misunderstandings?					
Did you find it easy to get answers to any questions you had?					
Was the technology (AR, 360° video) comfortable to use?					
Was it easy to find your way around the technology?					
Was it easy to move from one step to the next using the technology?					
Did you feel that the technology helped you learn?					
…					

OBSERVATION (CLASSROOM TRAINING AND LIVE TRAINING)

This template is for multiple learners for one major activity or task.

Activity													
Observer													
	Qs	**Help**	**Step 1**		**Step 2**		**Step 3**		**Step 4**		**Total**		**Level**
Name			Time	Error	Time	Error	Time	Error	Time	Error	Time	Error	

Note on columns:

- Questions – these are questions seeking to clarify process, get feedback etc. Ignore 'interest' questions e. g. asking for more advanced knowledge.
- Help – where the learner is stuck and needs the trainer's help to move on.
- Time – to complete the step.
- Errors – number of obvious errors at the end of the step.
- (If there are no clear breaks in the process, ignore the intermediate steps).
- Level – decide on a scale e.g. 1-5 each with clear criteria (e.g. novice-to-expert definitions, see end of document).

Comments:

Add your comments e. g. about learners' engagement and 'flow', and for technology-mediated groups their ease of use of the technology.

ASSESSMENT (CLASSROOM TRAINING AND LIVE TRAINING)

This is a rough outline as there may be other requirements e. g. if it is contributing to certification.

Learner:

Assessor:

Date of assessment (and how long after training):

Description of task or activity:

EQF/national level if relevant:

Success criteria (these will normally be, or be an expansion of, the learning objectives):

Criterion	Achieved	Comments

For the task overall, what level of proficiency did the learner reach? (Use a scale with clear description – see the example at the end).

LIVE TRAINING OBSERVATION.

Provide a clear description of the task, and a short set of success criteria. These could be the same as the assessment criteria, or they may be 'scaled up' for proficiency in the workplace.

Questions for supervisor:

Are there any criteria that the learner has difficulty meeting?

How well does the learner perform the task/activity as a whole? (Suggest using a 5-point scale such as novice to expert, with a short description of each level – see end of document).

How confident is the learner in doing this task unsupervised? (scale)

How confident are you that the learner can do this task unsupervised? (scale)

Any additional comments? Is there anything else that we could have done in the training to improve the learner's level of proficiency?

APPENDIX 3: Scenario planning template

SCENARIO		(CLASSROOM OR LIVE TRAINING)

LEARNING CONTENT PHASE	**WORKING STEPS (LEARNING ACTIVITIES)**	**TECHNOLOGY**	**COMMUNICATION & COLLABORATION**	**TEACHER ACTIVITIES**
Analysis/Orientation (xx min)				
Execution (xx min)				
Assessment (xx min)				

APPENDIX 4: Technical requirements for scenario materials and the LMS

Photos, graphics, pictures

Format

- JPEG – JPEG is the best option for photographs and other images displaying a wide variety of colours.
- PNG – PNGs for graphics, drawings, text, and some screenshots.

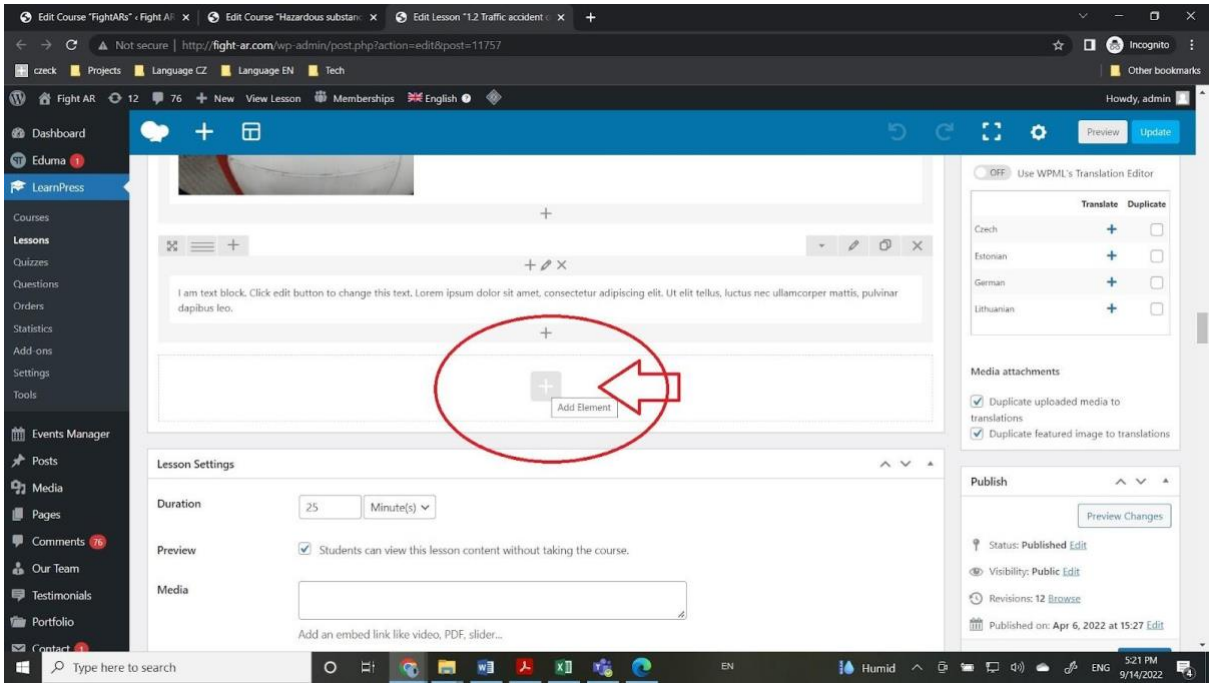
Size I would suggest the below:

- 1200 pixels wide: 394kb
- 1000 pixels wide: 298kb
- 800 pixels wide: 219kb
- 600 pixels wide: 154kb

Grouping

Try different variations of grouping the photos.

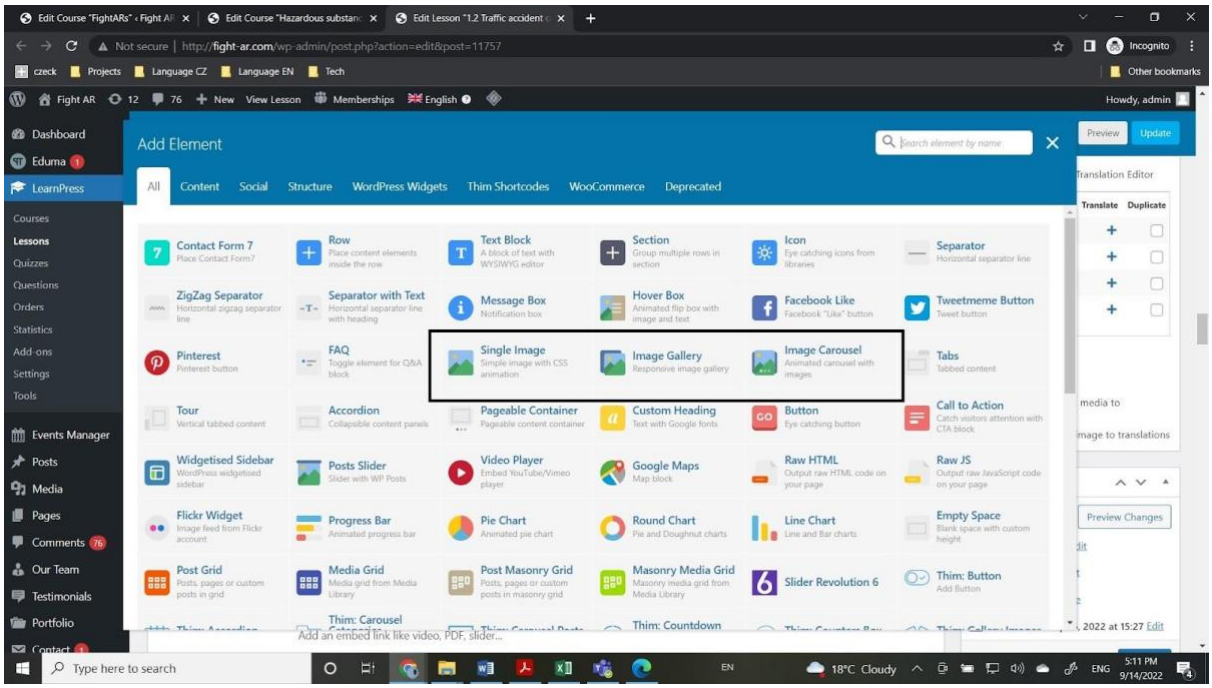
Go and choose the element that suits you the most:



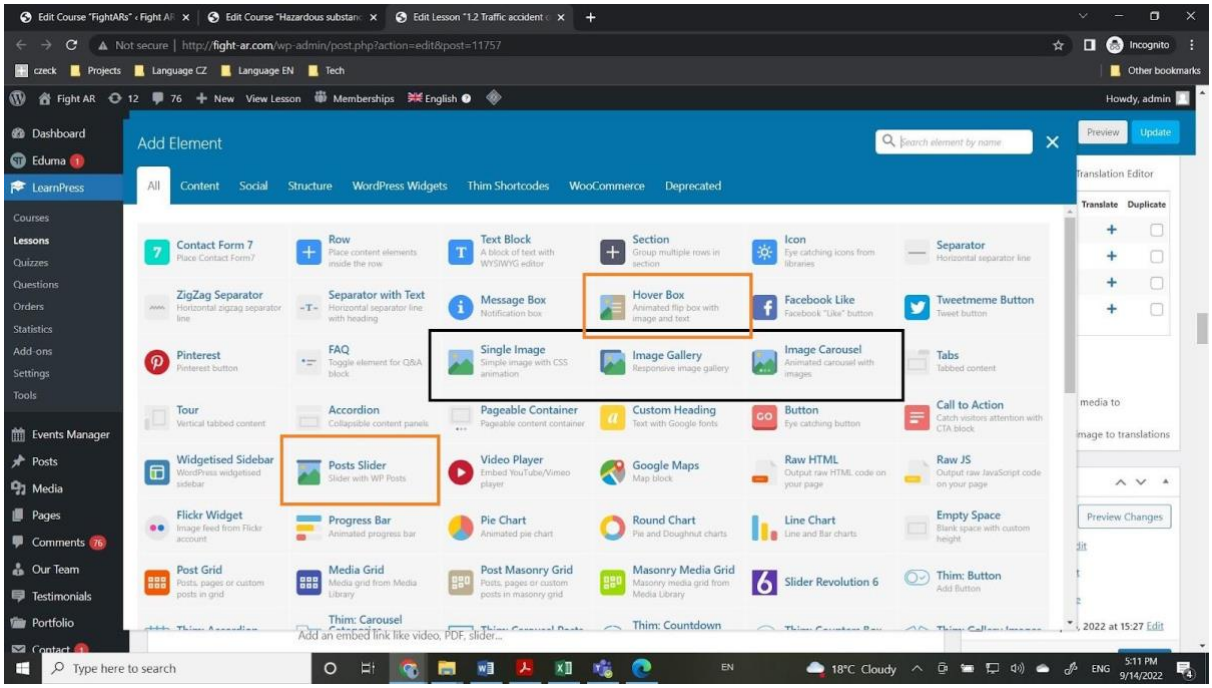
Each element gives different possibilities to group/ present photos or galleries.

Please pay attention to:

- Consider the end goal - what / how learner needs to evaluate information?
- How would it look with Hololens2? And how easy would it be to go from one photo to another?
- Would it be visible on a small screen, e.g. table, mobile phone?



Extra not usual grouping or presenting photos are these (in orange):



Hover Box

- Attention: Learner may not know that he/she needs to hover over the photo to reveal text

Caption

- All photos / galleries should have caption **under + centred in the middle**
- Compose caption including **Title + (source: xxx)**, e.g.:
  - Engine nr2 (source: EASS)
  - Engine nr2 (source: www.title.com)
- If you have **more than 2 photos** in the section - you need to include **numbering**:

    - Figure 1. Engine nr2 (source: EASS)
- Choose font “Paragraph”

Videos

Videos can be uploaded directly to Youtube, so the best quality you can achieve is suggested, and the user can control the quality that is best for his connection

Caption

- All videos should have caption **under + centred in the middle**
- Compose caption including **Title + (source: xxx)**, e.g.:
    - Accident scene with electrical car (source: SPSCH)
    - Accident scene with electrical car (source: www.title.com)
- If you have **more than 2 video** in the section - you need to include **numbering**:
    - Figure 1. Engine nr2 (source: EASS)
- Choose font “Paragraph”

Privacy

Where to take photos / pictures from:

- Please take your photos / create it by yourself
- Take from internet with free licence or if needed to cite the author or source

LMS

Hyperlinks

- Do not forget to mark “Open in the new tab” option
- Recommendation to put it on the Source if you include a website link (it is easier for user)

Fonts

Choose these fonts:

- Paragraph content: choose “Paragraph”
- Main title: “Heading 1” + capital letters
- Following titles (if/when needed): “Heading 2”, “Heading 3” + capital letters
- Captions: “Paragraph” - lower letters

Do not go further than “Heading 3”

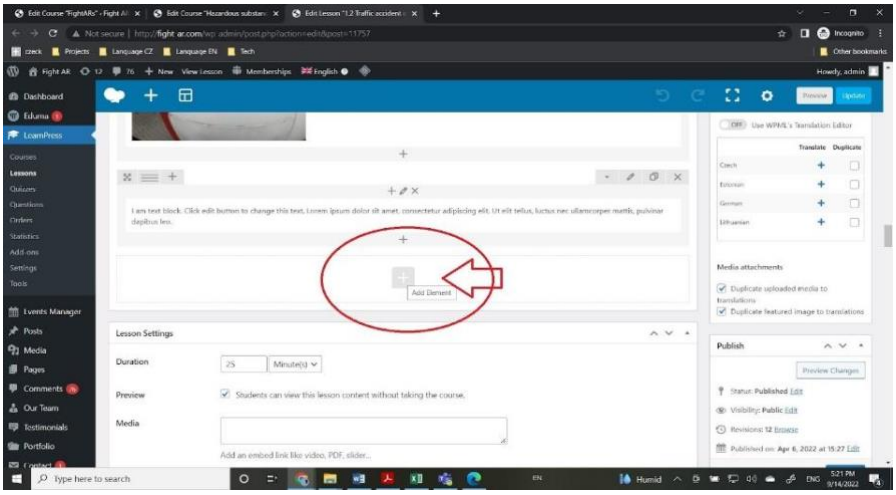
Tables

- Naming:
    - Classification of airbags
- Font: “Paragraph”
- Location: On top, before the table
- Numbering (if there are more than 2 tables in one section/lesson):
    - Table 1. Classification of airbags
- Caption: including it under the table, centred left

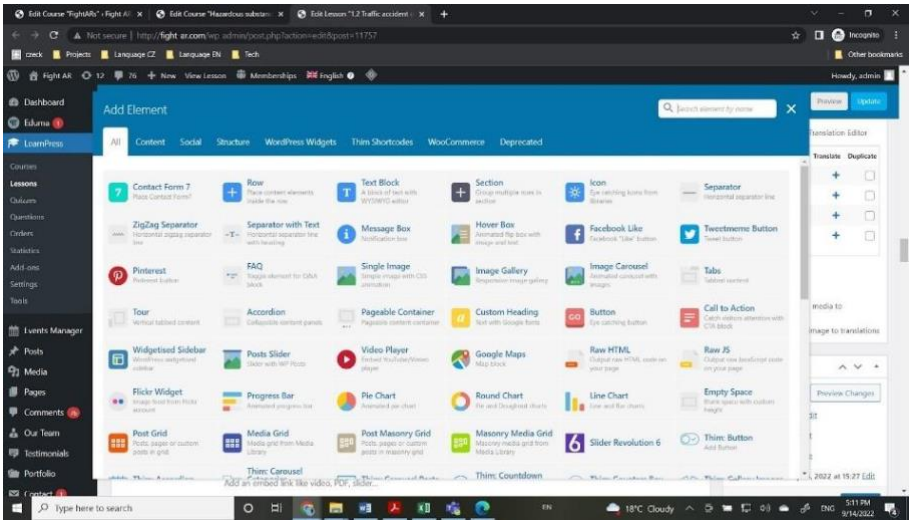
Structuring information

Wordpress provides different options for compiling information.

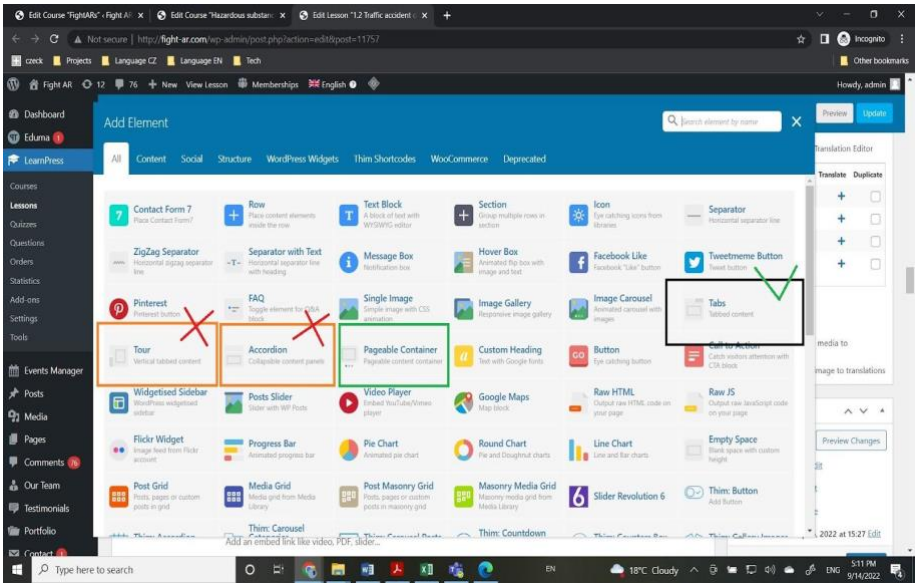
Go and choose the element that suits you the most:



You have many options:



Our recommendations:



Recommended: TABS
Why?

- It does not use space like others
- It is easier to navigate on computer and on Hololens2: going from one part to another
- Be careful with long titles of tabs

Less recommended: Accordion
Why?

- It is compact
- It requires to scroll more if you want to close/open it / going from one part to another if there are several opened

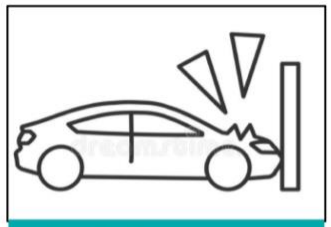
Not recommended: Tour
Why?

- Easy to navigate through parts
- It takes a lot of space from the left side even if title just a dot/number

Not sure: Pageable Container

- You need to check it

APPENDIX 5: Lessons learned from testing the FIGHTARs app



Crashed car: cutting

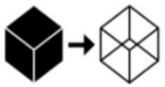
Beginner (guided by Software)

Expert (explorative)

Rescue person

Beginner (guided by Software)

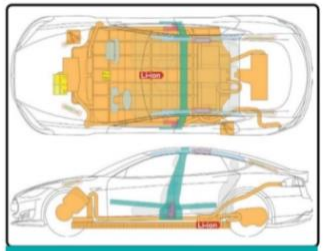
Expert (explorative)



Digital Twin

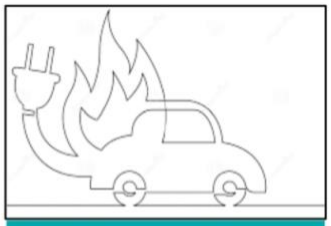
Car type/s (e. g. Tesla Model S)

Select car type



Battery pack location

View

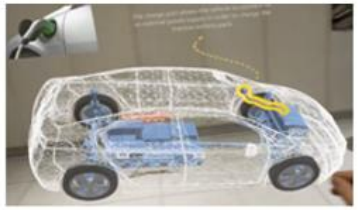


Fire: Extinguishing

Beginner (guided by Software)

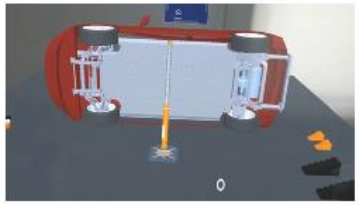
Expert (explorative)

Deactivation Battery



- Indoor use only
- Pinning of model in space needed
- Access to LMS contents (extra window in app)

Car cutting



- Indoor use only
- Pinning of model in space needed
- Tools selection requires with airtouch requires training

First aid

- Indoor use, outdoor use possible (single case and triage) to train situational awareness
- Overlapping of Avatar with real dummy easily possible
- LMS provides further input on procedures

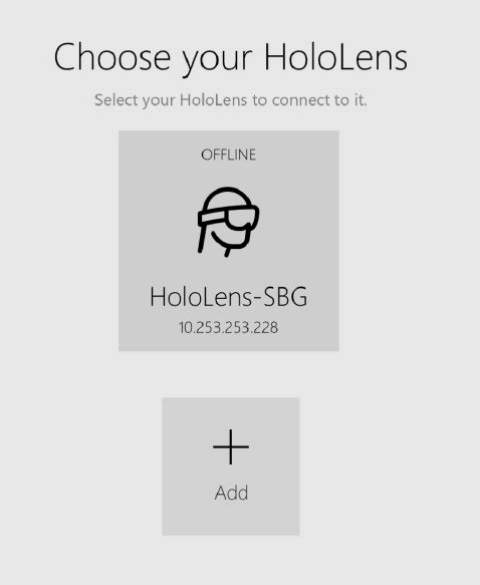
Hazardous substances

- Indoor use preferred
- Scaling and working around of virtual scene possible
- Integration of more hazardous material labels required
- Pinning LMS window in space good

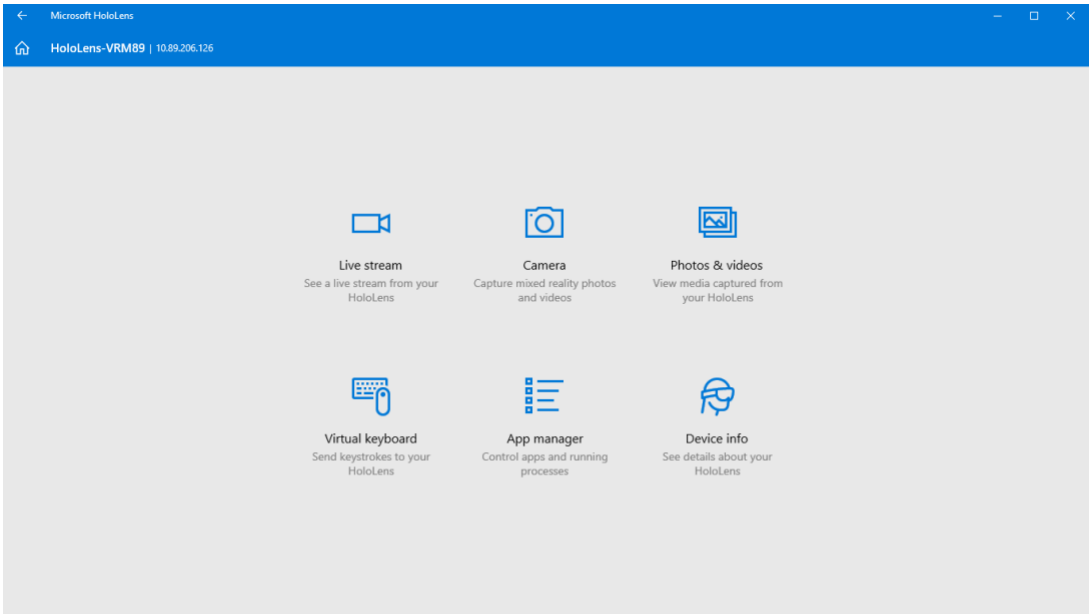
APPENDIX 6: How to set up the AR glasses to screen share

When the AR glasses are connected to the Wi-Fi, the IP address (IP 4) can be seen.[3]

By downloading the HoloLens App from the Windows App store, the screensharing can be easily carried out, if your PC or Laptop is in the same Network as your HoloLens. Just activate the button (see below).

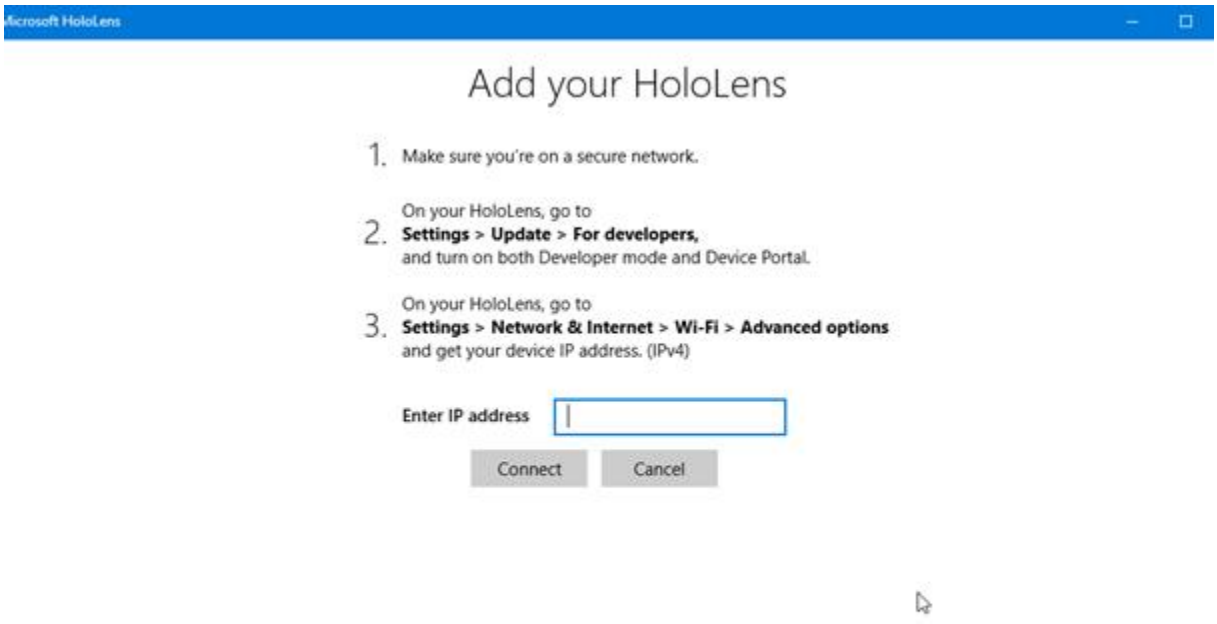


This will allow you to share your screen.



[3] Older Networks might not be compatible.

Note: It could happen, that the HoloLens App does not find the network (see below). Then enter the IP address manually. If this does not work restart your PC/Laptop and the HoloLens, and try it again. This procedure normally works.



Note on using the **Remote Assist** App (Microsoft Dynamic 365 suite):

The use requires HoloLens 1 or HoloLens 2 with the Remote App installed as well as a PC/Laptop/Tablet with Microsoft teams. It is also possible to use Remote Assist between a smartphone (with the app) and another smartphone with Microsoft teams installed. This allows solely 2D views in comparison to the 3D experience of the HoloLens use.

A remote assist call is the easiest between two persons from the same company or organisation. A person, which shows up in the contact list can either be called from PC/Laptop/Tablet or the HoloLens.

The installation of the remote assist app on the HoloLens normally requires admin rights.

The remote assist app can be booked monthly or longer by the admin.

The use requires a functioning Wi-Fi with a good bandwidth.

APPENDIX 7: FIGHTARs app voice control commands

Main Scene

- Car components
- Car chassis
- Deactivation
- First aid
- Hazardous substances
- Accident
- Stabilized and cut
- About
- Exit

Car components

- Show Menu
- Hide Menu
- Show battery
- Show body
- Show Cables
- Show charging port
- Show Converter
- Show engine
- Show web info
- Return

Car chassis

- Show Menu
- Hide Menu
- Show pillar A
- Show pillar B
- Show pillar C
- Show chassis
- Show front cross member

- Show front side frame
- Show deformation element
- Show side sill
- Show web info
- Return

Deactivation

- Show web info
- Return

First aid

- Show Menu
- Hide Menu
- Start Scan
- Stop Scan
- Show web
- Return

Hazardous substances

- Return

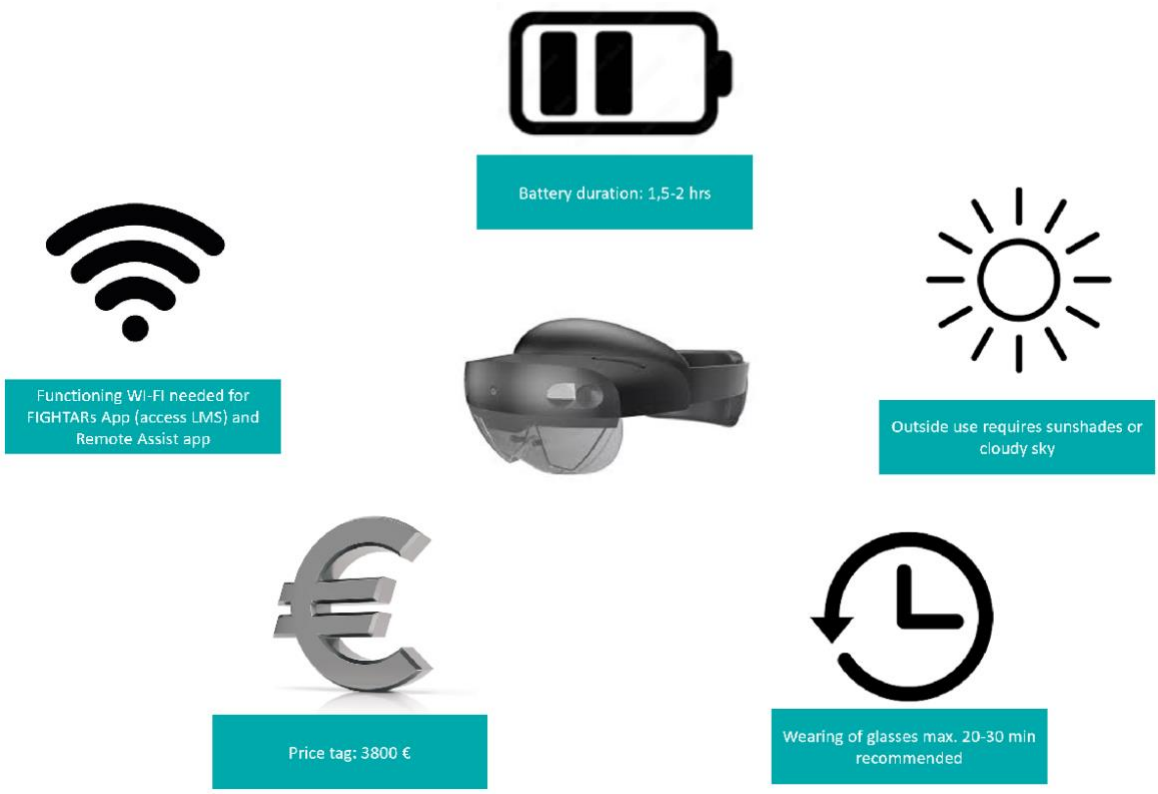
Accident

- Show menu
- Show web
- Return

Stabilize and Cut

- Return

APPENDIX 8: Limitations of AR use in firefighters training and ways to overcome them



Possible solutions:

Battery duration: have cable extension with you for charging (in pause mode or also during operation if it does not hinder the using)

Sun: It is possible to have sunshades for the HoloLens 2 ("HoloTint")[4]. There is also modification of the HoloLens 2 for a use with a safety helmet (Trimble HoloLens 2)

Wi-Fi: A training ground with poor Wi-Fi prevents the use of the Remote Assist App and the LMS function of the FIGHTARS app.

Duration: More training with the HoloLens 2 will results in longer usage times.

Price tag: Buy a used HoloLens 2 or wait for further AR glasses. If you are only interested in the remote assist function, you can also buy a Vuzix smart glass (lie Vuzix Blade). The price tag is around 1000 €.

[4] https://www.microsoft.com/en-us/d/trimble-holotint/94bvb2zp0vsf (04.10.2022)

APPENDIX 9: References

[1] SIZING UP" EMERGING TECHNOLOGY FOR FIREFIGHTING: AUGMENTED REALITY FOR INCIDENT ASSESSMENT (Katelynn A. Kapalo et. al., Proceedings of the Human Factors and Ergonomics Society 2018 Annual Meeting)

[2] Using Serious Games and Virtual Simulation for Training in the Fire Service: A Review (Williams-Bell et. al., Fire Technology, 51, 553–584, 2015)