AR and VR Meet Boiler Suits: Deriving Design Elements for AR / VR Trainings in the HVAC Industry

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Abstract: In the past few years, Virtual and Augmented Reality developed into a major technology trend that seems promising also for (further) education. New opportunities arise and need systematic evaluation. The research project ARSuL focuses on AR / VR based support functions and learning offers for HVAC (Heating, Ventilation and Air Conditioning) craftsmen. In this paper, we derive user-specific design elements for AR / VR trainings for this special target group from a comprehensive requirements analysis. Further, we outline a first AR / VR learning scenario that we substantiate using a combination of knowledge and cognitive process dimensions and learning scenarios for virtual / augmented worlds.

Introduction

Just a few years ago, virtual reality (VR) was used exclusively for military training purposes, product engineering, in the entertainment industry as well as for scientific purposes in research with strong visualization requirements. The solutions have often been complex, stationary, and expensive. The resource intensive development and installation inhibited a wide dissemination. It is only the new generation of devices with head-mounted displays (HMD) which provides affordable mobile settings of high quality and which makes VR and augmented reality (AR) becoming increasingly interesting and useful for the private sector (Sag, 2018). Subsequently it is worth asking whether and how VR and AR can enrich the education and training sector. Immersive, contextual learning outcomes offer at least theoretically the advantage of an authentic learning environment as it is demanded by the Constructivist Learning Theory. Multiple senses can be engaged more intense and simultaneously. New input and output devices increase the scope for action of students and teachers. Changes in perspective become possible, physical laws can be suspended, extreme situations can be approached risk-free, and information can be added optionally into reality. However, such potentials are exposed to various challenges since, e.g., design requirements for virtual learning worlds and significant research studies on the learning effects of VR / AR learning applications are currently still rare. The use of VR and AR settings has to offer a significant added value in order to justify the associated effort. The integration into a didactical framework and the monitoring of the learning progress, considering concrete objectives and level of learning accordingly have to play a central role (Schulte, 2017).

Against this background, the project "Augmented Reality basierte Unterstützung für das Lernen im Sanitär-Heizung-Klima-Handwerk (ARSuL)" ["Augmented Reality Based Support for Learning in the Heating, Ventilation and Air Conditioning (HVAC) Industry"], which is subsidized by the German Federal Ministry of Education and Research, aims to promote the development and evaluation of AR / VR based support functions and learning offers for craft enterprises and its employees. In the HVAC industry innovation and product cycles are becoming ever shorter, requiring a continuing education and flexibility of the employees. A tailor-made qualification and direct support relating to the specific work context of AR and VR seems to be obvious and promising. The present article investigates the suitability of AR / VR for practical vocational craftsmen training. User-specific requirements are derived based on a methodological triangulation, transferred into design elements, and implemented into an exemplary learning scenario. The developed learning scenario is based on the types of knowledge dimension and the categories of cognitive process dimension as suggested by Anderson and Krathwohl (2001), as well as the learning environments in virtual worlds according to Schwan and Buder (2002) and Weise and Zender (2017). Answering the following research questions, our paper addresses crucial didactic elements of an educational AR / VR scenario and derives an exemplary AR / VR training setting for apprentices in the HVAC sector in specific:

(1) What are the main requirements for AR / VR based trainings for craftsmen in the HVAC industry?
(2) What design elements for AR / VR trainings can be derived from the identified requirements?

(3) What conceptual recommendations for AR / VR trainings can be derived from the knowledge and cognitive process dimensions from Anderson and Krathwohl (2001) in combination with the VR learning scenarios identified by Schwan and Buder (2002) and Weise and Zender (2017)?
(4) How could an exemplary AR / VR training for the HVAC industry look like when considering the derived design elements and the differentiated AR / VR learning scenarios?

The mentioned research questions will be answered chronologically in the following sections.

Augmented and Virtual Reality and the ARSuL Project

AR / VR - Definition and Tools

Milgram and Kishino developed in 1994 the "reality-virtuality continuum", which postulates a continuous transition between real and virtual environments. The left area of the continuum defines environments, which are composed of real objects (cf. Fig. 1). The right area defines environments, which are composed of virtual objects, e.g., Google Tilt Brush. Within this continuum, 'mixed reality' (MR) is defined as an environment in which real and virtual objects can be combined in any form. While in augmented reality the 'real' amount prevails, in augmented virtuality the virtual amount dominates.

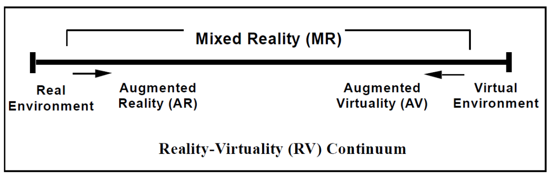

Figure 1: Reality-Virtuality Continuum (Milgram, Takemura, Utsumi, & Kishino, 1994).

Virtual reality is an immersive, interactive, multisensory, user-oriented, synthetic environment (Cruz-Neira, 1993), which integrates the user in a complete computer generated environment, namely the information (Bricken, 1990). Augmented reality, however, expands the real environment through virtual objects. It is characterized by an interaction in real time and a three-dimensional link between virtual and real objects (Azuma, 1997).

Diverse tools and devices can be used to experience this type of reality, from low-cost alternatives using smartphones via Google Cardboard, to smartphone cameras or high-end devices, like e.g. the Microsoft HoloLens. In favor of a strong immersion, so-called head-mounted displays (HMD) are currently used as output devices, which in addition stand out due to their mobility. While VR head-mounted displays close users off the reality, AR smart glasses project further information into the real field of vision. In the domain of VR, controllers have been established as input devices and control units, which are tracked (as well as the users are) to understand the movements in a room. In AR, usually haptic gloves and gesture recognition are used. In addition, high quality settings put emphasis also on acoustic, haptic, and olfactory feedback in order to increase immersion. In the near future, further developments can be expected regarding size, weight, battery life, and output quality of the HMDs, but also with regard to a more intense feedback, e.g. through data suits.

ARSuL Project

The ARSuL project (Augmented Reality Based Support for Learning in the HVAC Industry), funded by the Federal Ministry of Education and Research of the Federal Republic of Germany, focuses on lifelong learning. Until the end of 2019 the aim is to develop a system that assists HVAC craftsmen at their workplace and in addition during their vocational and further training with the help of e-learning, AR, and VR technology. Therefore, the project is divided into the two main parts support and learning. The authors of this paper are responsible for the latter as they are working on a teaching and studying approach that ensures training and qualification in line with demand and regarding the working context. Besides the South Westphalia University of Applied Sciences, the Ruhr West University of Applied Sciences, the Hochschule Niederrhein (University of Applied Sciences), the heating manufacturer Vaillant, and the Central Agency for continuing vocational Education and Training in the Skilled Crafts are part of the consortium project. In addition, four craft businesses with more than 15 employees each are involved in the project as associated partners.

Requirements Analysis

To derive the requirements of HVAC craftsmen concerning trainings with VR and AR technologies, we followed the requirements engineering approach (Nuseibeh & Easterbrook, 2000). For this purpose, a first workshop with the craftsmen of the associated partners was carried out. As a result, personas were derived and problems of this target group identified. After that, a methodological triangulation containing job-shadowing visits, a guided interview with a training engineer, and another second interactive workshop with the craftsmen were conducted. The results of these three inputs were then merged and analyzed to derive design elements for VR / AR trainings. Each step with its main outcome is outlined in the following, prior to a tabular summary of all identified requirements and the derived design elements for AR / VR trainings. Thus, the first two research questions will be answered hereafter.

Job Shadowing Visits

During job shadowing visits, project team members conducted field observations, by accompanying the employees of the associated craft business for a whole working day. Thus, an overt observation was possible since there was no artificial situation. The primary goal was to gain insights into the working day of the craftsmen, the work circumstances, and processes. To not influence the behavior of the craftsmen, no protocols were written during the participatory observations on-site (Döring & Bortz, 2016). During the visits, it became clear that the employees make a point of a personal togetherness and flat hierarchies among each other. Further, they need to deal with a broad variety of heating models from different manufacturers even though there is usually hardly or no time for preparation for an individual case concurrently. Usually, information about the model or age group of the individual heating is available only on the day of the operation or even on-site. Especially in the area of repairs, solution-oriented acting, instant detection of faults, and defects are important, since work orders often only contain the perceived symptoms by the customers (“It’s cold.”; “There’s a weird sound.”), but the customers expect a fast remediation. Regular trainings for knowledge acquisition and repetition are accordingly important.

The heating manufacturers address this need with trainings free of charge, which are considered as good and important by the participating craftsmen. On the other hand, the expenditure of time interlinked with travel and practice time are rated (too) high by the craftsmen. Moreover, the expectations of the supervisors seem to be misdirected: Even without relevant applications, repetitions, and refreshers the training content is expected to be retrievable at any time.

Furthermore, the worksite itself poses a problem for apprentices of the companies, who should learn from observations of fellow workers and active collaboration at the worksite. Often, it is not possible to observe process sequences in narrow rooms. Respectively it is very important for the apprentices to gain insights into practical work at the vocational school, too. However, the differently equipped vocational schools and educational centers, which are prevalent in craftsmanship, are as well not able to cope with the variety of heating models and their dynamic development and oftentimes only have old models on-site.

Finally it should be noted, that the craftsmen don’t see any problems with new installations of unknown products (as the device guides through the installation process), but mainly with maintenance and repair work. Also with regard to the set-up of a new heating systems a need for training was apparent, as standard settings of newly installed devices are rarely adjusted to the individual houses.

In the opinion of the craftsmen, their profession and especially their apprenticeship is rarely digitized so far. Accordingly, the craftsmen were mostly unfamiliar with the opportunities of learning with new technologies (applications, web-based trainings, learning videos, etc.).

Guided Interview

The 2-hour interview was conducted during the first workshop with a training engineer from Vaillant, recorded, and subsequently transcribed (Küpper, 2017). Prepared questions were asked about the trainings offered and the potential use and benefits of AR, VR, and e-learning, which were supplemented with further spontaneous questions during the interview.

An important part of the interview were the free trainings offered by Vaillant for heating engineers, which usually consist of a theoretical and a practical part. The latter takes place with training equipment provided at the training centers of the manufacturer. Depending on the number of devices provided in the corresponding training center, it may happen that not every participant can apply the learned content immediately in practice. The interviewee sees the mentioned circumstance as an opportunity for the use of VR. It would enable each participant to train work processes without real training equipment. In addition, the following training challenges were detected: (1) The field of trainees is very heterogeneous. The work-experience, learning speeds, and the existing knowledge of the participants differ significantly. The training engineers pay special attention to the use of simple language, which nevertheless contains the special terminology of the HVAC industry. (2) Moreover, during the trainings, the craftsmen are in an unfamiliar situation, as they usually engage in a physically active work routine. Therefore, they feel more comfortable in the practical part of the training and attach more importance to it. (3) The training engineer also reported a, in his experience, mostly extrinsic motivation of most participants. They usually are signed in by their superiors and are initially skeptical. Nevertheless, participants are asking many questions so that there is a lively exchange of problems and solutions among them.

Workshop

Three apprentices, four workers, and a managing director of the associated partner companies attended the second workshop, which focused on requirements analysis. The intended technologies were presented to the participants in a different, non-specialized context to show what is technically possible, without influencing the later conducted brainstorming session (Rupp, 2014). Using the ‘Walt Disney’ creative method based on the ‘Six Thinking Hats’ by de Bono (1990), three stations from the perspective of a dreamer, realist, and a detractor had to be completed in small groups successively in order to develop and discuss requirements for AR / VR supported trainings in the HVAC industry.

Among others, the desire for a voice control that can answer subject-specific questions was expressed. The desire goes hand in hand with the requirement that only little text should be used. Moreover, AR / VR should not only be used for training, but also for learning progress review. In this context, it became clear that trainings currently lack transparency and that craftsmen would like to have feedback on their learning progress.

For apprentices, the possibility to make mistakes in VR settings could be promising. Causal relationships could be experienced without the risk of negative consequences. Furthermore, a gamification approach, with the possibility to activate new teaching content, competitions, rankings, or multiplayer modes was identified as desirable. From the point of view of the workshop participants, learning scenarios that allow apprentices to learn and experience exam-relevant subjects in a practical way could significantly improve and enhance their learning experience. Practical exams were also cited as a conceivable and desired learning scenario.

Apart from that, workshop participants also expressed the concern that the quality of viable AR / VR learning settings would not be sufficient to achieve the desired benefits. Moreover, they demanded an overall concept, based on the discussed requirements with a consistent evaluation. As result, it would be necessary to check systematically to what extent VR / AR training courses can complement or even replace trainings on a real heating.

Requirements and Design Elements for AR / VR Trainings

The following table summarizes the requirements identified with the help of the methodological triangulation. It further provides the design elements, which have been derived from the requirements in a discussion among the project partners.

Table 1: Identified Requirements and Derived Design Elements.
(Abbreviation of the sources: V = Job Shadowing Visits; I = Interview, W = Workshop)

		Requirements	**V**	**I**	**W**	**Derived Design Elements**
A: Scenario Design	A 1	Casual cooperation and flat hierarchies among craftsmen	x			• Casual way of addressing users (on first-name basis) • Personalized way of addressing users
	A 2	Exchange among colleagues		x		• Multiplayer mode • “Craftsman” (Avatar) guides through the setting
	A3	Simple language including technical terms		x		Simple formulated content (visual/ auditory) by using common technical terms

		Requirements	V	I	W	Derived Design Elements
	A4	Desire for system that can be controlled by using the own voice			x	• Simple navigation • Voice control
	A5	Desire for system that answers questions and supports in case of problems			x	Problem recognition with context-sensitive guidance/ assistance (visual/ auditory)
	A6	Adapting training to usual active daily working life		x		• Short learning units • Demand for interactions
	A 7	Little text			x	• Multimedia presentation of content • Alternative presentations for different types of learners
	A 8	Feedback regarding the learning progress			x	• Feedback regarding (un-) solved tasks • Awards (badges)
	A 9	Quality scenario (realistic)			x	Realistic visualization of models/ components
	A 10	• Product variety should be representable in training centers because ○ No time for preparation/ post-processing in daily working life ○ Different levels of quality in apprenticeship	x			Scenarios for different heating models/ production years
	A 11	• Previous knowledge/ work experience varies • Apprenticeship varies because of (non) available heating models		x		• Options for individual learning speed with (automatically adjusting) assistance • Levels of difficulty (with and without assistance)
	A 12	• Learning content/ trainings often dismissed as irrelevant • Only extrinsic motivation		x		• Learning objectives pointed out clearly • Displaying the relevance of the content for daily work • Support of intrinsic motivation, e.g., by interactive tasks to unlock new learning content
	A 13	Studying with new technologies is largely unknown	x			• Introducing users to the system stepwise • Plain interface • Simple navigation/ interaction
	A 14	Causal research particularly important for apprentice	x			Possibility of riskless troubleshooting
B: Learning Content	B 1	Fast, solution-oriented behavior, and causal research are important	x			Setting should focus processes of the heating and functions/ connections of the different components
	B 2	Installations are guided by the heating, but configuration with regard to the house isn't done very often	x			Scenarios in which users have to configure the heating regarding different houses/ flats
	B 3	For maintenance work, experiences in causal research are important as customer's wish fast problem solving	x			Scenarios in which users need to find causes of problems and do maintenance work afterwards
	B 4	Learning content/ trainings are dismissed as irrelevant		x		Tasks/ problems for scenario derived from real world
C: Other	C 1	Retrieving knowledge earned once at any time is the expectation of customers and superiors	x			Cost-effective, space-saving settings, and easy to use settings
	C 2	Desire for overall concept			x	Overall learning scenario with sequences/ trainings that are connected thematically to each other ("Storytelling")

Concept & Learning Scenario for AR and VR Trainings in HVAC

In the late summer 2018 a first VR / AR test setting shall be implemented and evaluated as part of a build-and-evaluate loop within the ARSuL project. The learning objective of the test setting is the replacement of the blower in a heating model. It includes the following elements that will be taught in that order during the session: Components of the heating system and their collocation, function role of the components, work steps of the replacement process, removal, and installation process. The developed learning scenario is based on the previously derived requirements / design elements, and further on the taxonomy of educational objectives according to

Anderson and Krathwohl (2001) and the VR learning environments (which we also found to be suitable for AR) as differentiated by Schwan and Buder (2002) and Weise and Zender (2017). We will shortly explain the taxonomies before we then outline the resulting learning scenario for the test training. In section “Learning Objectives and Environments” the third research question will be answered, in “Concept & Scenario” the fourth one.

The Taxonomy of Educational Objectives

The taxonomy of educational objectives by Bloom et al. (1956) is a framework to classify learning objectives. The authors identified three categories of learning: the cognitive (knowledge), the affective (attitude), and the psychomotor (skills) domain. Anderson and Krathwohl (2001) revised this taxonomy on the cognitive domain, which comprises the knowledge dimension and the cognitive process dimension. In Anderson and Krathwohl's revised version, the cognitive processes and the knowledge dimension are combined to a matrix, whereas the original taxonomy remained one-dimensional. The knowledge dimension represent a range from concrete (factual) to abstract (metacognitive) knowledge. “Factual knowledge is knowledge of discrete, isolated content elements […]” (p.27 Anderson & Krathwohl, 2001), which could be, e.g., terminology or specific details and elements. These are the basic elements one must know to be familiar with a discipline or solve problems. Conceptual knowledge on the contrary is a more complex and organized form of knowledge that includes the interrelationships among the basic elements within a larger structure. This includes, e.g., classifications, categories, and principles. The procedural knowledge is the knowledge of how to do something and includes methods of inquiry and criteria for using skills, algorithms, techniques, and methods. Metacognitive knowledge is a new category of the knowledge dimension added by Anderson and Krathwohl (2001) and stands for the knowledge of cognition in general as well as awareness and knowledge of one’s own cognition.

The cognitive process dimension represents a continuum of increasing cognitive complexity with the six categories: Remember, Understand, Apply, Analyze, Evaluate, and Create, which are meant as hierarchical levels (Krathwohl, 2002). According to Anderson and Krathwohl (2001), ‘Remember’ describes a retrievement of relevant information from long-term memory, which is a simple recalling or recognizing process. Whereas ‘Understand’ is a construction of meaning from instructional messages and is expressed by interpreting, exemplifying, summarizing, inferring, comparing, or explaining information. The category ‘Apply’ goes one step further and means to carry out or use a procedure in a given situation. Cognitive processes linked to this category are executing or implementing a procedure to an (un)familiar task. ‘Analyze’ means breaking learning material into constituent parts and resolve how the parts relate to each other or to an overall structure or purpose. Differentiating irrelevant from relevant or important from unimportant parts of information, organizing, and attribution are the processes behind this category. Making judgments based on criteria and standards refers to the ‘Evaluate’ category, which includes checking information on inconsistencies or critiquing. The last category ‘Create’ relates to the generation of hypotheses, planning, or devising tasks and producing a product. This means to “put elements together to form a coherent whole” and to “reorganize elements into new pattern or structure” (p. 67 f., Anderson & Krathwohl, 2001).

VR Learning Environments

Schwan and Buder (2002) differentiate the following fundamental VR learning environments: Exploration, Training, Experiment, and Construction. Furthermore, Weise and Zender (2017) add an Exposition environment and sort the learning environments according to their level of interaction. In addition, they sort the learning environments according to their level of interaction. The following enumeration starts with the lowest level.

‘Expositional environments’ are suitable for learners with an extrinsic motivation and low prior knowledge. The learners are guided through the virtual world, which is characterized by much reduced interaction possibilities. The depth and the sequence of the learning content are predefined (Weise & Zender, 2017). In ‘explorational environments’ the users are able to investigate the information in self-imposed order, level of detail, and pace (Schwan & Buder, 2002). It should not only be possible to look at the visualized facts from different content-related perspectives, but also to literally take different perspectives, as users have the possibility to view at the virtual objects from different points of view. In these environments, the focus lies on the process of understanding and the transfer of declarative knowledge. The pedagogical orientation therefore is a constructivist one. A virtual museum in which all exhibits can be explored in any manner would be an example of such a learning environment. ‘Training environments’ in contrast aim at the transfer of procedural skills (Schwan & Buder, 2002), like in driving or flight simulators. In training environments, lecturers and learning objectives have a bigger meaning, which results in less self-directed actions by the learners. While the didactical design of ‘explorational environments’ is characterized by a constructivist concept, ‘training environments’ are designed in a behaviorist or cognitivist manner. ‘Explorational environments’ transfer knowledge with the help of static facts, whereas ‘experimental environments’ use dynamic topics. Causal relationships are taught with the help of simulations in which the parameters can be changed. From the observed effects conclusions can be derived, which helps to make the learning matter more comprehensible (learning by discovering) (Schwan & Buder, 2002). ‘Constructional environments’ are based on a deductive approach. Already acquired knowledge can be reviewed by the users through creating objects or even virtual worlds on their own (learning by design) (Schwan & Buder, 2002).

The described environments relate to VR settings, and we found no similar approach for AR. The VR environments can be partly applied to AR though, as Exposition, Exploration, and Training suit AR technologies as well. In contrast, the environments Experiment and Construction are based on the fact that in VR the laws of physics can be repealed and that mistakes do not have any real consequences. Learners thus need to interact with virtual elements and the consequences of their actions can only be shown virtually. Thus, it is questionable, whether such settings can be created using AR technologies.

Learning Objectives and Environments

The taxonomy of learning objectives and the classification of VR learning environments described above lead to the question which environment is particularly suitable for addressing different learning objectives. Figure 2 shows our suggestion of how to combine the matrices including the knowledge dimension and the cognitive process dimension with the learning environments Exposition, Exploration, Training, Experiment, and Construction. The resulting classification provides instructional designers guidance regarding what VR / AR learning environment to choose for specific learning objectives.

Exploration and Exposition are covering the same cells as they are very similar - in both environments processes of comprehension are focused. They spread over all cognitive process dimension categories on the most concrete level of the knowledge dimension, the factual one. Nevertheless, those environments seem to be suitable for more abstract knowledge types as well, as long as the thinking skills are on lower levels. Training seems to be usable for all categories of the cognitive process dimension within the category of procedural knowledge. Furthermore, Construction and Experiment are also covering the same cells because both are used to teach mental models regarding complex facts. They seem to be suitable for high order thinking skills on the level of the conceptual knowledge. The cells of the metacognitive knowledge are not covered with one of the outlined learning environments because based on the mentioned definitions there is no learning environment that suits well to the learning objectives of this dimension.

The different elements of the learning scenario for our test setting, or rather the learning objectives that correlate with these, can be classified with the revised version of Bloom’s taxonomy by Anderson & Krathwohl. First of all, learners get to know the different components that are involved and their collocation within the heating model. These are the basics they need to know for the upcoming steps. Therefore, this learning objective is in the cell of the lowest category of the cognitive process dimension and the most concrete type of knowledge (1) (see figure 2). After that, learners become familiar with the function role of the already mentioned components. They need to understand the interrelationships. Thus, it is the conceptual knowledge, which needs to be understood (2). Following, the work steps of the replacement process are explained. This learning objective could also be found on the second lowest category of the cognitive process dimension, but it is based on procedural knowledge, which is consequently more abstract (3). Until this point, learners were imparted knowledge they need for the process and subsequently they carry the different work steps of the removal and installation process out. This learning objective is part of the procedural knowledge type and refers to the middle level of the cognitive process dimensions Apply (4).

With the help of the suggested allocation, the authors derived the learning environments to be used for the determined learning objectives. Therefore, the components of the heating system, their collocation, and their function role will be taught with Exploration. For the work steps of the replacement process the environment Exposition is used, whereas a Training environment seems to be suitable for the removal and installation process.

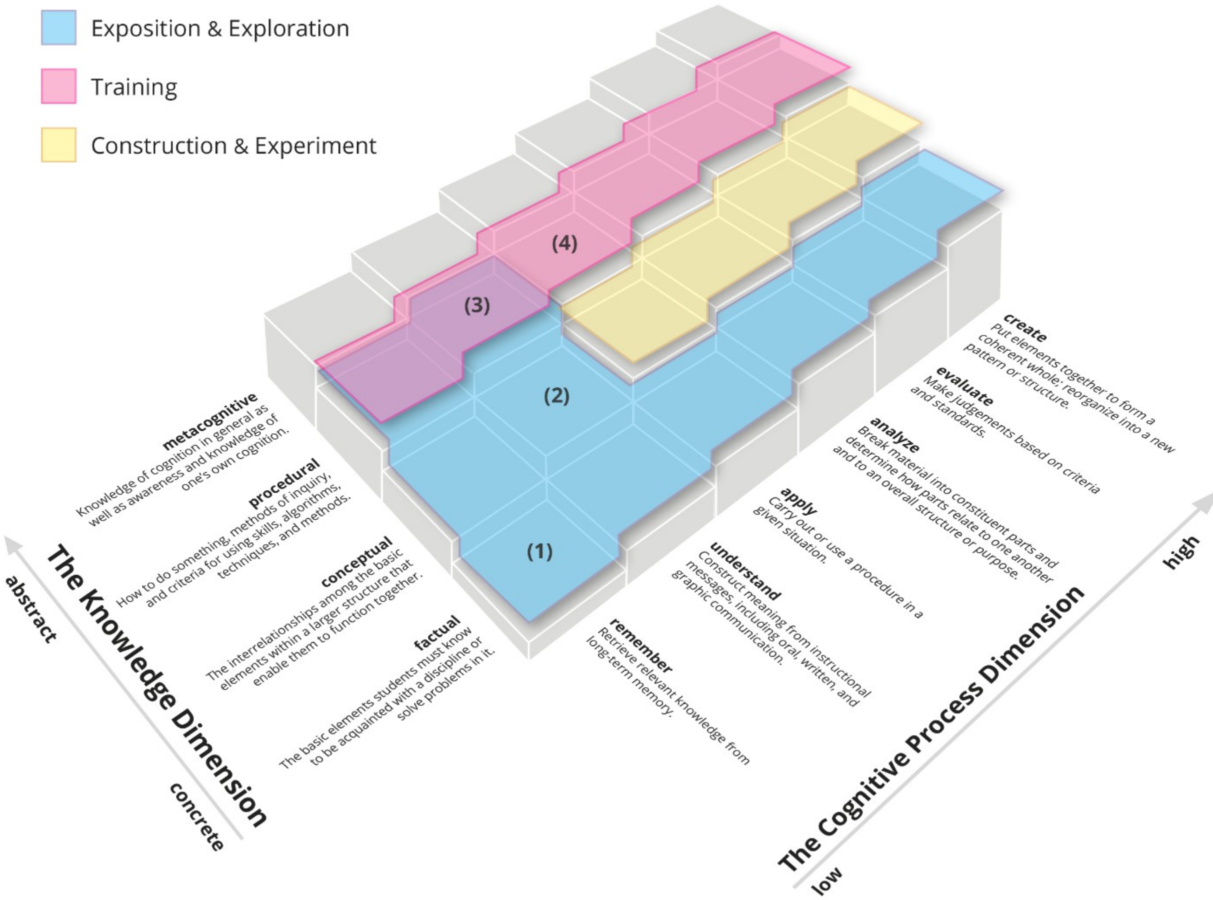

Figure 2: Bloom's revised taxonomy (Anderson & Krathwohl, 2001) in combination with VR Learning Environments by Schwan and Buder and Weise and Zender (Own representation, modified and expanded based on Heer, 2012).

Concept & Scenario

The topic of the test setting described above is the replacement of a blower in a heating model, which is content-wise a standard activity that apprentices of the HVAC industry need to master with confidence in their everyday work. During the test setting, our goal is to compare the effectiveness of different media types (AR, VR, e-learning application) in different learning environments. Therefore, the learning scenario for the test setting needs to be clearly defined and limited referring only to the learning objectives described above. As a result, not all design elements identified (see Table 1) will be implemented in the test setting: the elements A2 (multiplayer modus), A8 (learning progress in a bigger scenario), A10 (covering different heating systems), A12 (relevance of the general context), B2 (special case), and C2 (overall learning concept) will be excluded. The resulting learning scenario as derived from the mapping of the learning goals and the learning environments (see figure 2) is shown in figure 3.

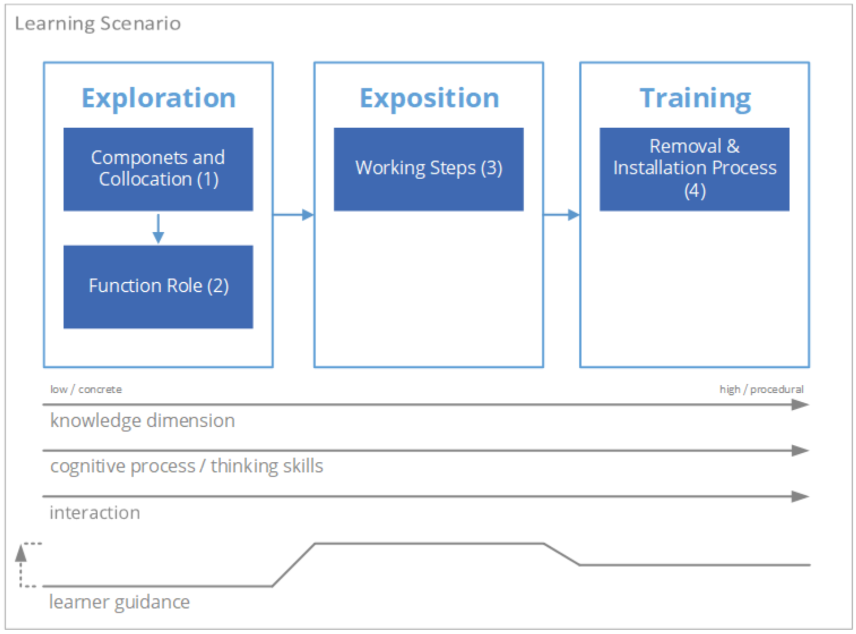

Figure 3: Learning Scenario for ARSuL Test Setting.

As objects, the AR / VR scenario includes the heating model and a table where parts are placed and users can drop components. Visual hints are especially presented in the form of colored marking of different components. In addition, arrows will show directions of movement. Text insertions are mostly renounced due to a bad readability. The voice of a speaker and (background) noise in accordance with interactions (falling down of parts, heating system working) are the auditory input. Besides acoustic feedback and force feedback is implemented. That is suitable for supporting the first steps of the diagnosis process or to point out an incorrect workflow. In the VR setting, users have controllers and see them as virtual hands that react humanely when moving the controllers or pressing buttons. When users look down they see a tool belt where they can choose the right tool. By means of rotary motion, e.g., screws can be tightened or loosened. Whether users in this first setting can use their own voice for interaction is a suspect matter. The VR system recognizes when working steps are completed successfully. This is considered for the AR setting as well by means of sensors. As long as this is not possible users need to select answers to short questions that appear.

The setting starts with a tutorial that guides users through the possibilities of navigation and interaction. In the course of the following sequences the users' guidance increases: First of all, users explore the components involved and their functions freely. During this, they can choose the amount of information presented regarding the different components. Then, they get to know the upcoming workflow. Afterwards, those processes are performed by the users themselves. For this sequence there is the option of choosing a level of difficulty: with or without instructions. At any time, users have the opportunity to change the setting for single sequences but also for the whole scenario. In case the instruction mode was chosen and the user selects the wrong part several times, colored marking or moving arrows support the user. If this does not lead to the desired result, the function to repeat the explanation is pointed out. Further, a help option is available that provides personalized assistance, either with error detection (e.g. "You did not loosen that screw.") or by calling up the workflow (e.g. "Have you already loosened all screws?".).

Conclusion

In this paper, we describe a requirements analysis made by means of a methodological triangulation. Job shadowing visits in HVAC companies, a guided interview with a training engineer and a workshop with HVAC craftsmen were conducted to identify specific requirements for VR / AR trainings for this target group. Table 1 summarizes the identified requirements and the design elements derived for AR and VR settings. The design elements serve as guidance for the aspired learning scenario of a test setting that we intend to accomplish in the late summer 2018. We defined and categorized the learning objectives that should be addressed in this learning scenario with the help of Bloom's revised taxonomy of educational objectives based on Anderson and Krathwohl (2001). We extended this model by combining it with the VR learning environments of Schwan & Buder as well as Weise and Zender (see figure 2). With help of these conceptual recommendations, learning environments can now be chosen with regard to the pursued learning objectives. Further, the suggested mapping reveals limitations, as there is no VR / AR environment yet that applies to the learning objectives of the metacognitive dimension. The transferability of the VR environments to AR is also limited. While the environments of Exposition, Exploration, and Training can be used for AR as well, the advantages of Experiment and Construction seem to be strictly bound to VR. There is a controversial debate in literature, whether an AR setting with users interacting purely with virtual objects and facing only virtual effects, can be considered AR at all.

As a prototype, the finally outlined learning scenario for the VR / AR test setting does not cover all identified requirements and all derived design elements mentioned in Table 1. This is an acceptable limitation as it is our goal to compare AR, VR, and e-learning in different learning environments for the different phases of the test setting with regard to transfer of learning, user satisfaction, and learning success. Based on our findings, we will then work on a larger and more complete learning scenario addressing also new content. As a direct next step, we now need to identify appropriate evaluation models for the test setting based on a structured literature analysis.

References

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives* (Complete ed.). New York: Longman.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, *6*(4), 355–385.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals*. Handbook 1: Cognitive domain. New York: David McKay.

Bricken, W. (1990). Virtual Reality: Directions of Growth. *Notes SIGGRAPH '90 Panel (HITL Technical Report R-90-1)*.

Cruz-Neira, C. (1993). Virtual Reality Overview. In *SIGGRAPH '93: Course Notes* (Vol. 93).

de Bono, E. (1990). *Six thinking hats* (Repr). London u.a.: Penguin Books.

Döring, N., & Bortz, J. (2016). *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften*. *Springer-Lehrbuch*. Berlin, Heidelberg: Springer.

Heer, R. (2012). A Model of Learning Objectives. Retrieved from http://www.celt.iastate.edu/wp-content/uploads/2015/09/RevisedBloomsHandout-1.pdf

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into Practice*, *41*(4), 212–218.

Küpper, M. (2017, July 12). Interview by K. Menke. Remscheid.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, *77*(12), 1321–1329.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282–293).

Nuseibeh, B., & Easterbrook, S. (2000). *Requirements Engineering: A Roadmap*. *ICSE'00. Proceedings of the Conference on the Future of Software Engineering*, pp. 35–46.

Rupp, C. (2014). *Requirements-Engineering und -Management: Aus der Praxis von klassisch bis agil*. München: Hanser.

Sag, A. (2018). CES 2018: Virtual Reality And Augmented Reality Get Another Shot. Retrieved from https://www.forbes.com/sites/moorinsights/2018/01/25/ces-2018-virtual-reality-and-augmented-reality-get-another-shot/#45983c5aab04

Schulte, F. (2017). (Virtuelles) Lernen hier, hier und hier, und (reales) Handeln dort – Die Bedeutung einer (Transfer-) Kompetenzorientierung bei der Gestaltung von Virtual/Augmented/Mixed Reality-Lernszenarien. In C. Ullrich & M. Wessner (Eds.), *Proceedings of DeLFI and GMW Workshops 2017*.

Schwan, S., & Buder, J. (2002). Lernen und Wissenserwerb in virtuellen Realitäten. In G. Bente (Ed.), *Internet und Psychologie: Vol. 5. Virtuelle Realitäten* (pp. 109–132). Göttingen: Hogrefe Verl. für Psychologie.

Weise, M., & Zender, R. (2017). Interaktionstechniken in VR -Lernwelten. In C. Ullrich & M. Wessner (Eds.), *Proceedings of DeLFI and GMW Workshops 2017*.