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Development of a Guideline Under Didactical Aspects for the Use of Immersive Virtual Learning Environments

Amelie Karcher[1] · **Dominik Arnold**[2] · **Bernd Kuhlenkötter**[2]

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Abstract
Quality methods are classically applied in productive and administrative business areas as well as in the context of qualification measures. This paper presents the development of a didactic guide for the use of immersive virtual learning environments, which focuses on the training of quality methods. The guide is an element of the design phase of the assisted reality implementation model (ARIM), which was developed as a unified approach for the creation, training and subsequent evaluation of quality methods using augmented and virtual reality (VR) glasses. Thereby, the didactic guideline is also methodically derived from the ARIM and transferred to a realized virtual learning environment. The guideline is intended to address the handling of necessary hardware, appropriate safety and hygiene precautions and finding one's way around the virtual learning environment. It thus serves as learning material for trainers and trainees alike. The following section explains in detail how the concrete guideline for self-directed training with VR should look and which specific requirements have to be taken into account. The aspects explained up to this point describe the structure of this article. In addition, an initial evaluation was conducted, which will be first explained with a description of the procedure and concluded with the presentation of the results. A brief conclusion is provided at the end.

Keywords Assistance systems · Virtual Reality · Quality methods · Virtual learning environment · Guide

Introduction

In a constantly changing world of work, where new technologies, methods and requirements are emerging, it is crucial for employees to engage in on-going training (Zimmermann, 2017). Through continuing education, employees can fully realize their professional potential and increase their performance (Asfaw et al, 2015). They can develop their existing skills, acquire new knowledge and keep up to date. This can lead to better quality of work, higher productivity and greater opportunities for career success (Asfaw et al, 2015; McDowall & Saunders, 2010). Continuing education thus helps employees expand their professional competencies, advance their careers and meet the challenges of a changing workplace. It is an investment in personal and professional development and can provide long-term benefits to both employees and companies (Halawi & Haydar, 2013). In addition, training that is flexible in terms of time and location is becoming increasingly relevant. Digitalization and the use of technologies such as e-learning platforms and online courses mean that employees can access continuing education content regardless of their location and time availability (Kerres, 2018). This enables a flexible design of learning that meets individual needs and schedules. In addition, sustainable continuing education in quality management systems using Virtual and Augmented Reality assistance systems is an exciting area of research. In the long term, various learning scenarios in the virtual learning environment (VLE) for learning quality methods, for example with the help of VR glasses, are to be realized. For a concrete implementation of such trainings, stand-alone VR glasses will be used, so that this innovative approach ensures a self-sufficient use of the system by the user. In addition, a self-determined use of this system enables above all learning at one's own pace, as well as learning by doing (Stuchlikova et al., 2017).

Possible areas of application for these technologies include so-called quality methods (QM) as taught in Lean Management and Six Sigma. They aim to minimize occurrences of errors in products and processes. The mentioned

✉ Amelie Karcher
amelie.karcher@ruhr-uni-bochum.de

[1] Ruhr-Universität Bochum, Bochum, Germany

[2] Chair of Production Systems (LPS), Ruhr-Universität Bochum, Bochum, Germany

quality management systems (QMS) have proven practical over decades, contributing to the efficiency and effectiveness enhancement in companies. The application of associated methods requires practice, for which VR/AR learning environments can be helpful by facilitating knowledge transfer and reducing barriers in subsequent practical application (Hussein & Nätterdal, 2015). These QMSs rely on optimizing business and process operations to enhance customer satisfaction through product quality improvement (Helmold, 2021). They enable the identification and optimization of the most common types of errors through a phased analysis of a process. The failure mode and effects analysis (FMEA) is one of the essential methods of Six Sigma, focusing on early error detection in products and processes (Su & Chou, 2008). Training sessions for QM, such as through workshops, are traditionally taught through in-person frontal instruction. This often results in significant travel and material costs (Freina & Ott, 2015). In the realm of virtual reality (VR), training and its location-independent usability not only enable more flexible training but, in comparison to traditional frontal teaching methods, can also enhance the efficiency of knowledge transfer, deepening and retention (Lau & Lee, 2021). Initial approaches in research indicate that the use of VR, for instance, in conjunction with Lean Management, is meaningful and supportive (Netland & Hines, 2021). It is crucial not only to analyse the current level of dissemination and specific applications of this technology but also to understand the practical handling of the technology and identify its peculiarities. For this reason, a systematic literature review (SLR) was conducted. During a systematic literature search, it was discovered that in the majority of projects carried out in the context of VLEs, an accompanying person was present, so that the self-sufficient approach can be regarded as innovative (Karcher et al., 2023). This results in new requirements for the implementation of the didactic guideline, since it can be assumed that the users will deal with the VLE independently. Another finding of the SLR is that VLE based on virtual and augmented reality are technically demanding and require specialized skills and resources to effectively design and implement them in educational contexts. The academic community and educators are often insufficiently prepared to make optimal use of these technologies. Despite the impressive technological capabilities of VLE, there is often a lack of an appropriate pedagogical framework to ensure that learning content is meaningfully and effectively delivered. Therefore, it is necessary to strike a balance between technology and pedagogical principles. With the increasing use of VLE in educational institutions and professional development, there is a growing need for best practices and guidelines to ensure the quality of the learning experiences. The transition from traditional teaching and learning methods to immersive virtual environments necessitates a revision of pedagogical approaches. Educators require support to optimize the learning process in these new environments. The intended pedagogical guide aims to assist educational staff in the practical application of VLE with learners. Of course, there are various other measures and support systems, which necessitate further research. A pedagogical guide for VLE is, therefore, essential to address these gaps, enhance the quality of education in immersive environments and promote the effective utilization of modern technologies in educational institutions. For

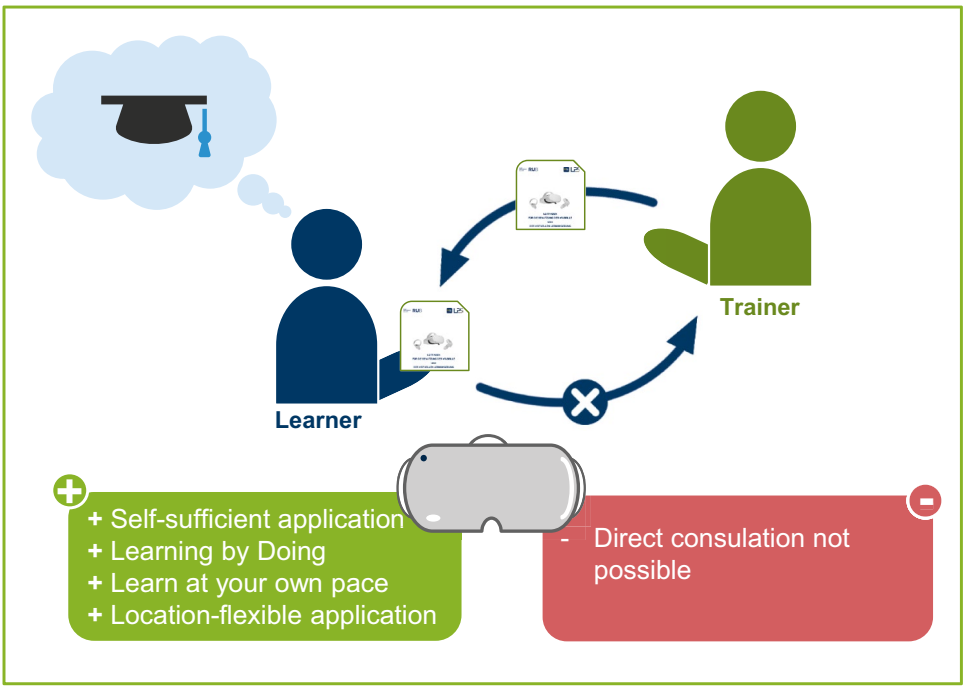


Fig. 1 Basic idea of the didactic guide

this reason, the scientific gap is to be filled, and a sketchy representation of the basic idea can be seen in Fig. 1. The intended development of a didactic guide is to facilitate the flexible use of immersive VLE so that users can engage with the subject matter autonomously. This will be tested for applicability and acceptance of the technical implementation in further research work.

A didactic guide is a pedagogical tool that serves as orientation and support for teachers, trainers or instructors (Kerres, 2009). It provides structured guidance for planning, designing and implementing learning processes. A didactic guide usually includes information about the learning objectives, content, methods, media and materials and organizational aspects of the learning process. It provides concrete instructions and recommendations to enable learners to learn effectively and in a targeted manner. For the VLE, action-oriented learning is emphasized and realized with the help of individual problems in the respective VLE. In action-based learning, learners are encouraged to become active, experiment, discover and gain their own experiences (Babel & Bernd, 2014). The focus is on active and practical engagement with a task or problem. It is a pedagogical method in which learners develop and apply their knowledge and skills through their own actions. Action-based learning goes beyond simply imparting knowledge and aims to have learners apply their knowledge and develop solutions in real or simulated situations. The research question is now how a didactic guideline for self-directed training with VR should be effectively structured. Likewise, the didactic guide to be developed here should not only be suitable as a printed piece for persons without digital competencies, but also self-explanatory, answering as many expected questions as possible. At the same time, it must also provide relevant information for people with digital competence. In conclusion to the preliminary considerations, the supplementary question can be formulated as to how the user can be introduced to the respective educational content of a VLE with as little effort as possible.

Didactic Guideline Development for Application for VLE

Assisted Reality Implementation Model

Based on the ADDIE instructional design model, the assisted reality implementation model (ARIM) was developed. ARIM is a linking approach of mechanical engineering, didactics, computer science and psychology, which is applied to implement immersive VLE of QM (Karcher et al., 2022) In this context, ARIM consists of three main phases: (1) potential analysis, (2) design and (3) validation. The design phase includes, among other things, the conceptual training design, for which the didactic guide is used to prepare the immersive VLE. An overview of the ARIM can be found in Fig. 2.

Methodology Used to Integrate the ADDIE and ARIM

Since the ADDIE model with its five phases of analysis, design, development, implementation and evaluation (Niegemann et al., 2008) forms the basis for ARIM, reference is also made to the ADDIE model in the creation of the guideline, since the additional extensive literature research conducted did not reveal any significant

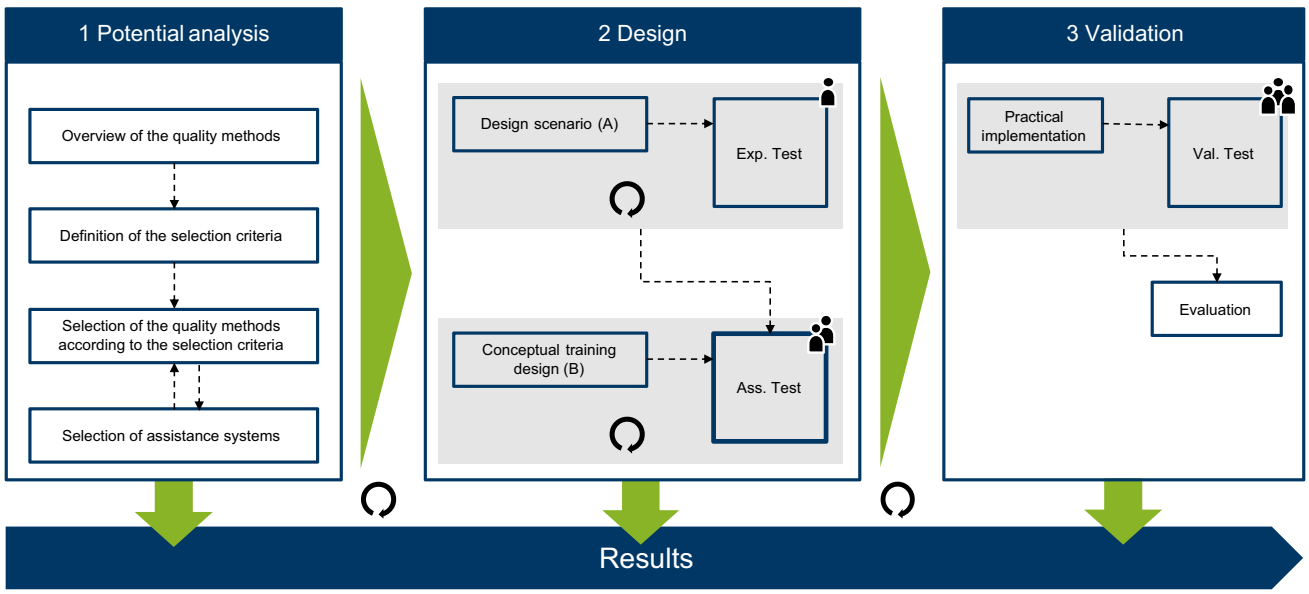


Fig. 2 Assisted reality implementation model — ARIM (Karcher et al., 2022)

additions. The ADDIE approach refers to the generic description of student learning, which is now applied to the learning situation of users and learning how to use VR glasses. The individual ADDIE approaches were reviewed for applicability and transferability to handling VR glasses. This analysis revealed that the following three approaches, which address user learning, are relevant and applied to the creation of the guide: *content introduction*, *supporting media to select or develop* and *learner guidance*. The approaches mentioned are sub-aspects of the ADDIE development phase, which is essentially concerned with the creation of training materials.

In the ADDIE model, the *content introduction* refers to the planning of e.g. presentations, role plays, peer teaching, case or project-based exercises (Branch, 2009). The didactic guide could be used as a presentation and is thus a potential parallel, but it differs from the other formats mentioned, so that only the general and no specific bases for the design of the guide can be adopted here. The content to be taught is the focus when it comes to actively engaging the learner in the process of building knowledge. This should be the focus of the design and should not be supplemented by unnecessary design elements.

Structure of a Guideline Under Didactical Aspects

In the ADDIE model, three common types of guiding information: (a) organization, (b) format, (c) quality to represent the content are presented. The typical elements of (a) organization include title page elaboration, copyright, acknowledgement page, table of contents, main body, glossary and appendix (Branch, 2009). A glossary and an appendix can be dispensed with for the intended guide, so the following are examples of the title page and table of contents. One requirement for the title page is that it should usually contain a thematically introductory graphic and be designed accordingly, especially if it is used as a cover page. A table of contents is a useful reference tool in any document that contains more than 20 pages. This is divided into several chapters, the largest structural component being the main section, where the content is placed for exercises or respective module, for example. Each of these sections should reflect the structural design as much as possible. This is basically built into the following, structural sections:

- An introduction to the subject
- An explanation of the new content
- Examples to illustrate the content
- Exercises in which participants can practice the new skills
- A summary of the topic (Branch, 2009)

These elements determine (b) the format. Regarding (c) the quality to represent the content, the clarity, accuracy and consistency of the document are to be realized, which have an influence on the presentation of the content (Branch, 2009). In addition, for the conceptualization of the guide, the method of 5 Ws — who, what, when, where, why and how — is used, which is located in the ADDIE evaluation phase (Branch, 2009). Thus, in the preparation of the didactic guide, the various questions should be used to clarify in advance which content is relevant, how it is presented and for what, if any, a special approach is necessary.

Examples include:

a) Who will do the implementation? (Personnel)
b) What specifically is to be taught? (Content)
c) When is the introduction to be carried out? (Timing)
d) Where will the introduction take place? (Location)
e) Why is this introduction important? (Purpose)
f) How will feedback on the guide be collected? (Instruments)

For the concept of training that is as self-sufficient as possible, the answers would be as follows:

a) The introduction is primarily analogue with the help of the guide, which is prepared like a hand-out.
b) The independent use of virtual reality glasses as well as the VLE should be taught.
c) The thematic introduction should take place before the actual application.
d) The introduction can take place independently of location and thus individually.
e) The guide serves to introduce the user to the topic and is a reference work to provide initial assistance in the event of challenges. At the same time, it can alleviate fears and inhibitions and points out necessary safety precautions. Users who are already experienced can access information according to their specific needs. For this purpose, the table of contents provides quick orientation.
f) Feedback on the guide should be provided during the test phase through observations and moderated discussion rounds. During later use, the contact option stored in the guide can be used.

In the concrete implementation, the mentioned aspects are addressed as follows: the guide is created in DIN-A4 format and starts with the title page including graphics, followed by a (1) welcome including a table of contents, ends with an acknowledgement and contact information. The table of contents consists of the (2) basic instructions, (3) introduction of the hardware, (4) setup of the VR glasses, (5) information about the procedure, (6) start

overview of the VLE, (7) cleaning and packaging and the offer of a (8) checklist. The table of contents can be found on each numbered page in small format. The corresponding topic is highlighted visually, thus allowing the user a structured approach to familiarization and orientation. Even if the guide has only nine pages and thus no 20 pages, a table of contents was decided for the reasons mentioned. Chapters 2 Basic instructions to 4 Setup of the VR glasses are initially intended to familiarize the participants with how the VR glasses work. Thereby, it is also explained how a comfortable wearing of the VR glasses is achieved and, for example, how the image sharpness can be optimized. Chapter 5, Information about the procedure, presents an overview of which questionnaires are to be completed for validation and at what point in time. Furthermore, concrete examples of the VLE are illustrated to meet the requirements for aspect (b) of the format. The 8 Checklist is intended to ensure that, on the one hand, no page is overlooked and, on the other hand, that the user can check for himself whether he has worked through all the sub-steps of the guide. In this way, different learning types among the users are considered individually. With the help of the checklist, the participants are supported in the process of independent and self-sufficient use. The requirements of clarity, accuracy and consistency with regard to the presented content and understanding are secured by a 4-eye-principle during the testing phase and represent questioning factors during the moderated discussion round. The created guideline is shown in excerpts in Figs. 3 and 4.

Evaluation of the Didactic Guide for the VLE

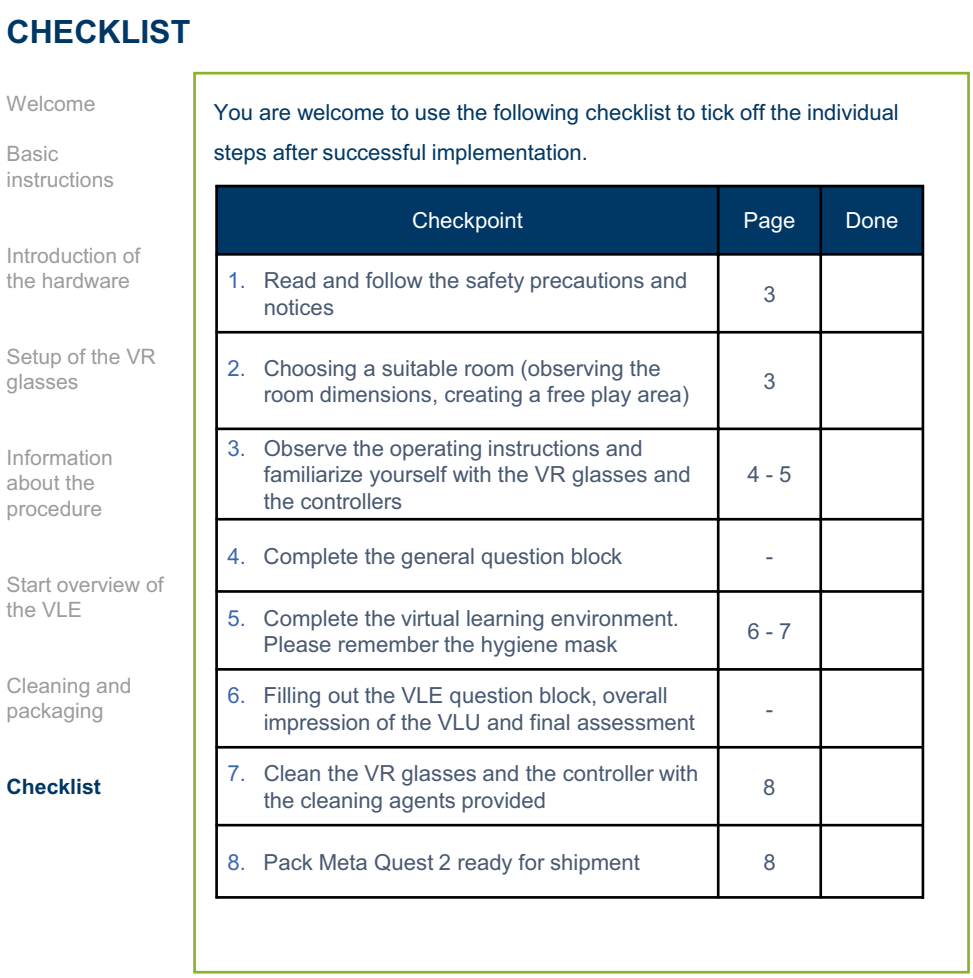
A group of 20 students and employees of the Ruhr University Bochum was selected for a VLE test on quality management systems (Lean Management and Six Sigma). The participants belong to the age group of 20 to 35 years and have different technical and methodological backgrounds, from beginners to skilled practitioners. During the validation of the Plan, Do, Check, Act and FMEA QM included in the VLE, the participants were given the described didactic guide for independent application. The participants had the opportunity to use the guide without time limitation. At the same time, they were observed remotely by the training staff and asked to describe their impressions in a moderated discussion. This allowed individual suggestions to be taken up and queries from participants and developers to be clarified. The first key finding from the discussion round was that all participants found the guide helpful and supportive. Further feedback can be categorized and summarized as follows:

Appeal for the Commissioning of VR Glasses

Chapter 5 Information about the procedure was perceived by four participants as an appeal to put on the VR glasses already when reading the guide for the first time, even though only general process information was presented in it. Three of the four participants subsequently noted that the information on starting the VLE was missing. They set down the VR glasses to access more information in the subsequent

Fig. 3 Overview of the didactic guide for immersive VLE

Fig. 4 Excerpt from the didactic guide — checklist



CHECKLIST

Welcome

Basic instructions

Introduction of the hardware

Setup of the VR glasses

Information about the procedure

Start overview of the VLE

Cleaning and packaging

Checklist

You are welcome to use the following checklist to tick off the individual steps after successful implementation.

Checkpoint	Page	Done
1. Read and follow the safety precautions and notices	3	
2. Choosing a suitable room (observing the room dimensions, creating a free play area)	3	
3. Observe the operating instructions and familiarize yourself with the VR glasses and the controllers	4 - 5	
4. Complete the general question block	-	
5. Complete the virtual learning environment. Please remember the hygiene mask	6 - 7	
6. Filling out the VLE question block, overall impression of the VLU and final assessment	-	
7. Clean the VR glasses and the controller with the cleaning agents provided	8	
8. Pack Meta Quest 2 ready for shipment	8	

page of the guide and were then able to successfully start the correct VLE. The process of setting down the VR glasses occurred more often for these four participants, so switching between the two media occurred more than once. It is important to avoid this media break as much as possible. As a consequence, the language of chapter 5 will be adapted and a note added stating that the VR glasses should not yet be put on. Further testing is required to determine whether the optimization encounters further challenges.

Starting a False VLE

Three participants started a VLE that was not part of the test scenario. When one participant asked whether the learning factory environment represented the correct learning scenario, the training staff instructed him to refer to the VLE to be tested. Here, no exact cause of the error could be identified in the follow-up. The point will be monitored further — currently, no optimizations for the guide can be derived. As described in chapter 5, some examples of the VLE are listed in the didactic guide. Here, a one to one representation by screenshots is used to increase the recognition value within the VR. To offer a better orientation to the participants between explanation within the guide and recognition in the VR, blue borders were used as an example of a concrete app. Through the possibility of the moderated discussion round, it could be determined with one participant that he interpreted the marked app as the VLE to be selected during the general explanation. This error needs to be corrected by replacing the screenshots. Likewise, the naming of the app "LFF" within the VR hardware caused another participant to select the app incorrectly, which should be corrected at this point in the future or is due to the internal reference of the group of participants.

Checklist

The 8 Checklist, which can be found on the last page of the guide, was rarely and only sporadically completed by the participants. Four of the participants completed the checklist of the guide up to the first three of a total of eight checklist items. When asked, participants responded that they were not aware of the checklist after completing the VLE. During feedback, three participants stated that they were aware of

the checklist but did not act on it. Three participants gave feedback that a checklist had not been necessary for them. One participant praised the checklist and would have liked to have worked on it but wished for a different positioning in the guide. A suggestion was made that the checklist and the table of contents could be combined in Chapter 1 Welcome. This suggestion can be included and evaluated in the future. Alternatively, a loose insert of the checklist is being considered so that it can be actively used at any time without having to turn the pages of the guide.

In summary, the feedback on starting the VR glasses and starting the VLE not correctly could be adjusted by minor measures. Some participants did not notice the checklist after finishing the VLE. For this reason, it is suggested that the checklist be placed after the welcome or offered as a separate insert. This should be tested in a further evaluation.

Summary

The didactic guide of the design phase of the assisted reality implementation model (ARIM) has proved to be a useful element for the training format during initial testing. The most important and unique features of the guideline from a didactic perspective for the use of immersive VLE include the following aspects. The guideline emphasizes a well-organized and pedagogically sound structure for immersive learning experiences. It incorporates strategies to enhance learner engagement, ensuring active participation within the virtual environment. The guideline focuses on leveraging multiple senses for a more immersive learning experience, catering to various learning styles. It provides a framework that can be adapted to various domains, ensuring versatility in application across different educational contexts. Specifically, this means that the guide supports the learners in effective and goal-oriented learning, as it provides instructions for action and recommendations. This is made possible above all by the self-sufficient and independent use, so that at this point, a lasting further training is promoted. The participants are given useful assistance in handling VR glasses. Likewise, the checklist included in the guide gives different learning types the opportunity to note their personal progress in learning VR and to work through the training individually. This is to be evaluated again by further research work for the future addressee group of the further training. The didactic guide additionally offers the possibility to be used as a practical reference book. During the testing, some suggestions were found, which were optimized and are now to be tested in a next evaluation.

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Data Availability All data generated or analysed during this study are included in this published article (and its supplementary information files).

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