Procedure for the implementation of VR/AR learning scenarios for method training - Presentation of the Assisted Reality Implementation Model (ARIM).

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Research Article

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Abstract

Virtual - and Augmented Reality (VR/AR) based assistance systems represent a growing technology approach for the sustainable communication of quality methods for further education offers. To create virtual learning environments as standardized and efficient as possible, a uniform approach is required. This paper focuses on the development of the Assisted Reality Implementation Model (ARIM) for the selection of Lean Management and Six Sigma quality methods that are suitable to be taught using augmented and virtual reality learning environments. Furthermore, the ARIM enables meaningful guidance for the implementation of the virtual learning environments, as well as subsequent validation. The model will be applied and evaluated within the research project WILLEN.

Data Availability Statements

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

Introduction

Exceptional situations, such as the ongoing COVID-19 pandemic, have been given little or no consideration in traditional forms of classroom training, highlighting the need for innovative approaches to knowledge transfer that also allow for location-independent forms of training. [1 -3] Especially the use of VR and AR systems offers opportunities in such extraordinary situations to continue to convey learning content sustainably. [4] In the field of VR, for example, this can be achieved through its location-independent use. Thus, training in such special situations is not only generally enabled, but can even increase the efficiency of knowledge transfer and deepening compared to classical frontal teaching methods. [2, 5] This increase in efficiency, which is made possible by the interactive and immersive VR applications, is based on the positive learning effects through an independent and tangible experience according to the learning by doing principle. [6,7] A location-independent use of VR systems enables a reduction of time and monetary expenses, e.g. travel and preparation times, travel costs, costs for energy or expensive consumables, which are used in classical face-to-face seminars. [6, 8, 9] VR also offers the opportunity to implement situations that in reality are extremely challenging, too dangerous or where access to them is not possible. [10 - 12]The experience of time travel to historical events is exemplary [10, 13], to name the free exploration of the universe and its planets and thus the overcoming of physical barriers. In addition, the limits of irreversible decisions in psychologically demanding dangerous situations, such as the training of fire brigades under realistic conditions, can be safely enabled [14, 15]. With AR it is also possible to display additional content and information in the real environment, directly in the user's field of vision. Especially in training, the transfer of knowledge can be supported by practical exercises and additional assistance using AR. Additional content can be e.g. maintenance plans for machines, instructions, logs or construction drawings. The use of these applications is therefore possible in many different industries and scenarios and a corresponding trend in the qualification with AR and VR technology is noticeable. The aim is to supplement the existing training measures and not replace them. [6]

The active use of VR/AR systems not only offers the advantage of a resource-saving learning opportunity, but also supports self-directed, individual learning. [2, 16] In this way, the users can determine their learning times and pace themselves, which makes it easier to impart knowledge, especially in the case of instructions for complex processes. The augmenting technologies mentioned actively focus on the users through the head-mounted display application. [6, 17] This focus on users is also found in the application of quality methods such as e. g. Lean Management, since the actors also play a central role here.

Application of VR and AR in industry

In an industrial environment, VR/AR assistance systems are one of the driving forces of digitalization. [6, 18] The rapid development of technical assistance systems is now opening up new areas of application for them. The constant digitalization of our society is conducive to the spread of such systems, so the availability of smartphones in the private sphere in industrialized nations is now taken for granted. [6] For decades, people have been dealing with portable hardware for displaying everything from digital content to virtual worlds, but it is only the latest developments that make these technologies usable in practical use. [6] Among other things, concepts for qualification measures and further training offers in the context of production can be supported. In addition to the production environment, assistance systems are also becoming increasingly important in the field of education. [6, 10, 19] For example, in medicine, the costly training of surgical scenarios is increasingly being replaced by VR and AR applications, or in service quality training for preclinical emergency personnel. [20, 21] The digitalization trend in teaching also promotes digitalization in further education, which leads to a positive trend in the use of VR and AR assistance systems [6]. In addition to an increased interest in VR in the engineering field, there is also an increase in the use of digital devices within learning and educational offers, as well as in educational research. [22, 23] In particular, VR/AR applications have great educational potential by making learning more motivating and inspiring. [24 - 26] Among other things, the three basic principles of immersion, interaction and user participation are fully taken into account when designing a VR application. [10] In the area of AR implementation, the design principles in the area of contextuality, interactivity and spatiality should be observed. [27] These interactive possibilities for users make VR and AR a promising technology for supported learning processes. [23]

Application of VR and AR in connection with quality methods

Quality methods, such as those taught in Lean Management and Six Sigma, help to optimize processes. These methods have already proven themselves in practice for decades and thus contribute to increasing efficiency and effectiveness in companies. The application of these methods requires practice, for which VR and AR learning environments can be a help by facilitating the transfer of knowledge and lowering the barriers in later practical application. [16] Corresponding ongoing and already completed research initiatives have addressed these

improvement options, but the concrete application is currently still scarce. [7, 9, 14, 28-31] Further research revealed that there are initial uses of these technologies in the area of quality methods, e.g. with the Virtual Quality Toolbox (VQT) [32]. The VQT uses VR technology in seven lessons for learning quality tools. These lessons are Pareto diagram, control chart, histogram, fishbone diagram, affinity diagram, why?-why? diagram and force field analysis. These quality tools incorporate statistical methods classically associated with Six Sigma. The VR applications have been recorded in the VQT as more attractive and convincing learning formats, in direct comparison to classical formats, e.g., exercises. Further, self-directed learning and illustrated interaction opportunities were rated as beneficial. [32] It should be noted, however, that no standardized framework for the implementation of such training offerings is apparent in the paper. Likewise, no holistic concept in the sense of Lean Management or Six Sigma can be identified, since the selection of the chosen methods was subjective. Schematically structured, specific VR/AR learning scenarios for Six Sigma with a focus on further training are not known based on current literature research. [33] This lack of a standardized framework for implementation means that current VR/AR learning scenarios can be found in a confusing variety of isolated applications and different implementation premises, such as visual design or even teaching methodology. Questions about the organization of such teaching/learning tools within the framework of institutional teaching/learning processes have also remained largely unresolved to date [34]. For this reason, the possibilities of the conceptual application of VR and AR in the context of Lean Management and Six Sigma are considered in more detail. For this purpose, the development of a holistic approach for the creation and validation of VR/AR learning environments for further training courses of quality methods is necessary and to be considered useful. This is intended to provide orientation for the creation of teaching units with virtual and augmented scenarios and is intended to show answers and possibilities as to whether and which quality methods from the area of Lean Management and Six Sigma can be sensibly implemented in VR and AR.

Research questions on the process model

Although initial research projects have dealt with VR and AR [7, 9, 14, 28 -31], a uniform, standardized approach to the selection, creation and subsequent validation of VR/AR learning environments has not yet been developed or established. The holistic approach of the process model is therefore intended to provide assistance to get out of the leading areas of quality management systems such as e.g. Lean Management and Six Sigma to teach different quality

methods using VR and AR. For this purpose, the author asks fundamental questions, to which the procedure should provide the best possible answers. The overarching challenge is to combine quality methods and technological assistance systems in a way that creates value. The following questions, which are divided into research question [R] and implementation question [I], were initially developed based on this starting position:

feasibility

    a) Which quality methods can be taught in a VR/AR environment? [R]

    b) Is it possible to map an overlap of higher-level management systems such as Lean and Six Sigma with the help of a methodical implementation? Can methods be tested for this synergy? [R]

    c) Are the desired quality methods fundamentally suitable for being illustrated in VR/AR? [I]

work organization

    d) What criteria are necessary to make a selection from possible quality methods? [R]

    e) Does an overview of the VR/AR assistance systems make sense, be it for the VR hardware and its specific properties, for example, to define further requirements for the implementation of the applications? [I]

    f) Does the selection of the assistance systems influence the selection of the quality methods? [I]

Application of the result

    g) Which technical requirements must be ensured by the users to be able to (efficiently) use the VR/AR assistance systems? [I]

    h) What training times should be observed to prevent cognitive overload? [R]

Requirements

    i) What are the basic requirements for creating VR/AR learning environments? [R]

    j) What are the didactic requirements for the implementation of teaching scenarios in VR/AR applications? [R]

Efficiency

    k) Can the targeted quality methods be evaluated relative to the effort and cost in VR/AR versus practical exercises? [I]

<u>Validation</u>

l)   How can the acceptance to use the assistance systems be checked? [R]

m) What tools are available to validate the approach? [I]

n)   Which requirements have to be met to ensure validation? [I]

The target is now to answer and validate these questions with the help of a structured procedure. This procedure model focuses on the implementation of reality-based assistance systems (=Assisted Reality Implementation Model - ARIM) in learning scenarios.

From ADDIE to ARIM

Assisted **R**eality **I**mplementation **M**odel (ARIM) is based on the principle of the ADDIE instructional design model resp. the product development paradigm with the five phases of analysis, design, development, implementation, and evaluation [35 - 37]. This approach is used especially in the design of teaching systems and especially learning environments [35, 36]. In addition, other models deal with teaching systems and learning environments, such as Gagné, Briggs, and Wagner, and the ID model of Dick and Carey. However, these do not consider the use of media and therefore do not provide media-specific design specifications. [35] Since the ADDIE approach is described as a generative model and concepts as well as theories are applicable to specific contexts [36], it serves as a basis for ARIM. The systematic structure of the ADDIE approach provides a framework for orientation, especially for complex situations, which is essential for a successful educational project [35, 36, 38]. This is reflected, for example, in the large number of successfully applied teaching and learning theories [36].
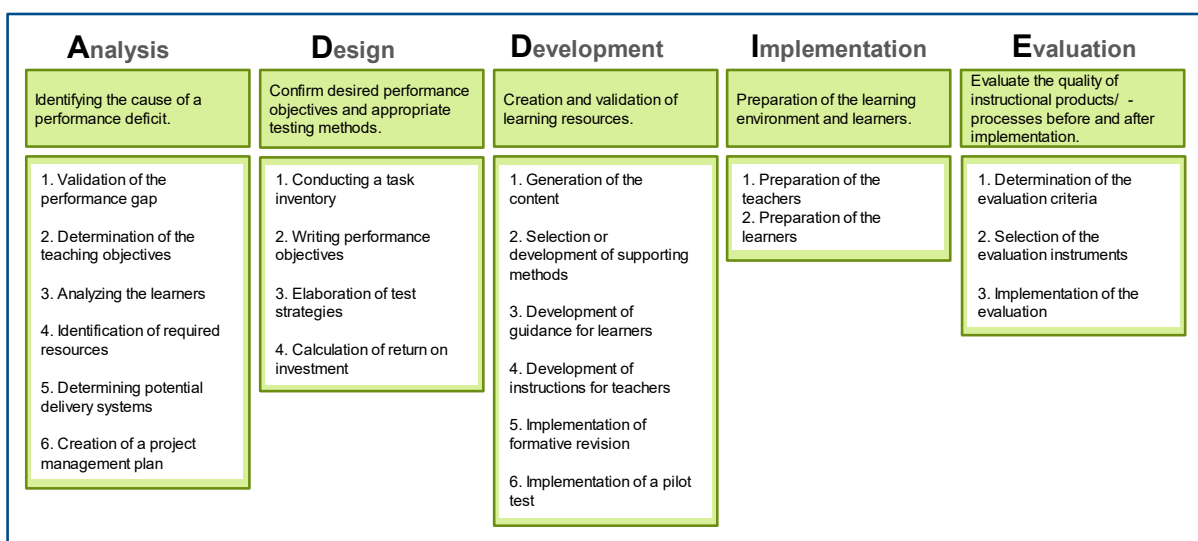
Analysis	**D**esign	**D**evelopment	**I**mplementation	**E**valuation
Identifying the cause of a performance deficit.	Confirm desired performance objectives and appropriate testing methods.	Creation and validation of learning resources.	Preparation of the learning environment and learners.	Evaluate the quality of instructional products/ - processes before and after implementation.
1. Validation of the performance gap	1. Conducting a task inventory	1. Generation of the content	1. Preparation of the teachers 2. Preparation of the learners	1. Determination of the evaluation criteria
2. Determination of the teaching objectives	2. Writing performance objectives	2. Selection or development of supporting methods		2. Selection of the evaluation instruments
3. Analyzing the learners	3. Elaboration of test strategies	3. Development of guidance for learners		3. Implementation of the evaluation
4. Identification of required resources	4. Calculation of return on investment	4. Development of instructions for teachers		
5. Determining potential delivery systems		5. Implementation of formative revision		
6. Creation of a project management plan		6. Implementation of a pilot test		

Figure 1: The ADDIE approach according to Branch 2009 / own illustration

The five ADDIE phases can be broken down into further sub-steps. For example, according to Brach, the **analysis phase** identifies the probable causes of an achievement gap and breaks this down into six sub-steps. These are 1. Validation of the performance gap, 2. Determination of the teaching objectives, 3. Analyzing the learners, 4. Identification of required resources, 5. Determining potential delivery systems (including cost estimates) and 6. Creation of a project management plan. Within the **design phase**, the desired deliverables should be identified and relevant testing methods should be reviewed. The design phase consists of four sub-steps 1. conducting a task inventory, 2. writing performance objectives, 3. Elaboration of test strategies and 4. Calculation of return on investment. The **development phase** is used to create and validate learning resources such as educational media and consists of six sub-steps. Beginning with 1. Generation of the content, 2. Selection or development of supporting methods, 3. Development of guidance for learners, 4. Development of instructions for teachers, 5. Implementation of formative revision and concluding with 6. Implementation of a pilot test. The subsequent **implementation phase** will be used to prepare the learning environment as well as the learners. Here, the sub-steps 1. Preparation of the learners and 2. of the teachers will be deepened so that an implementation strategy emerges. The final **evaluation phase** aims at the quality assessment of the teaching products and processes before and after the respective implementation. Here the sub-steps 1. Determination of the evaluation criteria, 2. Selection of the evaluation instruments and 3. Implementation of the evaluation are planned, so that an evaluation plan develops.

Due to changing learning environments caused by external influences such as technological tools, technological innovations, and flexible educational systems, the adaptation of the ADDIE approach is recommended [36]. Thus, this approach serves as the basis for building the targeted model for quality methods training using AR and VR learning environments. In this way, the model is verified in the first step and adapted to the specific requirements of the application area.

By focusing on the quality methods, the following characteristics can be stated for the ARIM according to the current status:

a) Due to the long-standing use of the quality methods established today, it is possible to fall back on existing learning content.

b) The target group of learners is already narrowed down due to the aspiration to use the developed learning environments in the field of (further) education.

c) Due to the requirements of an application that is as self-sufficient as possible, the role of the teacher is not in focus.

These characteristics should be taken into account when adapting the ADDIE model. In the following step, based on these characteristics, the listed research questions and the review recommended according to Branch, an analysis of the ADDIE approach was carried out to analyze the individual sub-steps and phases concerning their necessity, sequence and also extension. As the first intermediate results it was determined, that the analysis and evaluation phase can be taken over from their basic idea. However, individual sub-steps and even individual phases of the ADDIE approach cannot be adopted and must be elaborated accordingly for the procedure.

Starting with the analysis phase, the sub-steps 1-3 of the ADDIE approach cannot be adopted due to the characteristics a) and b), since an application of the classical quality methods in the area of further education is focused. Thus, an adaptation and specification of the sub-steps of the analysis phase is necessary. The goal of the newly created analysis phase is to analyze the potential of the quality methods for VR and AR. This is then to be named the **ARIM potential analysis.**

Characteristics b) and c) deviate from the original implementation phase and integrate it as a sub-aspect into the design phase. As an example, sub-step 6. "Implementation of pilot projects" of the ADDIE approach is now to be integrated into this ARIM design phase. The trigger for this is the possibility of multiple testing as well as validation of the individually self-sufficient applications, to test and check them for immersibility at an early stage. These additions of phase-specific tests are intended to counteract the late discovery of problems, which is criticized in the ADDIE approach [35]. Thus, the ADDIE design and development phases are bundled into a common **ARIM design phase**. A further adjustment is made for the sub-step 2. selection or development of supporting media of the ADDIE development phase. Especially for the application of VR and AR, the selection of hardware has high relevance for the overall process due to its functional properties, so this substep has to be done much earlier compared to the ADDIE approach. Therefore, this sub-step is integrated into the **ARIM potential analysis** because the virtual learning environment is built on the technology of the hardware. Consequently, the potential analysis should be completed first before starting the **ARIM design phase**. By restructuring the phases, **ARIM** can be divided into three phases, see fig. 2.
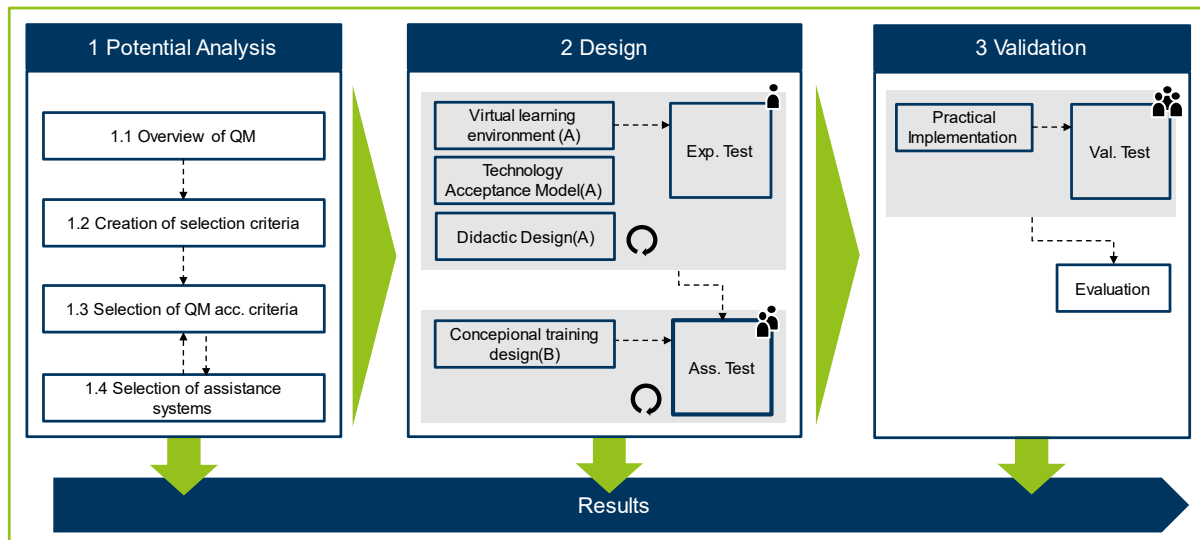
Figure 2: Assisted Reality Implementation Model (ARIM) | own illustration

First, there is a **potential analysis**, followed by a **design phase** and finally a **validation phase**. Each of these phases leads to intermediate results that have an impact on the following phase. In addition, these phases will provide answers to the previously mentioned questions regarding the requirements for ARIM. For example, questions a) to g) with the categories feasibility and work organization influence the ARIM potential analysis.

Each of these three phases (see fig. 2) is subdivided into further sub-steps. The **potential analysis** is divided into four sub-steps: 1.1 Overview of the quality methods, 1.2 Creation of the selection criteria, 1.3 Selection of the quality methods according to the selection criteria and 1.4 Selection of the suitable assistance systems. This mirrors, for example, sub-step 4. identification of required resources from the ADDIE approach. Back to the **ARIM**, steps 1.3 and 1.4 again have a special influence on each other, depending on the selection of the criterion and the assistance. This has the consequence that, depending on the selection of the quality methods, the selection of the hardware must be adapted – likewise, this can take place in reverse. This can be triggered, for example, by the situational requirement to work with existing hardware. This means that the selection of the quality methods according to the selection criteria can be made separately, but should be compared again with the overview of the assistance systems.

ARIM – Potential analysis

For sub-step 1.1 an overview of quality methods, a selection of suitable quality methods for a VR- or AR-supported learning environment must be made. To obtain an up-to-date overview

of the entirety of quality methods, training series and continuing education offerings, e.g., in form of workshops, are analyzed, supplemented with literature analyses, and validated with expert interviews. In a second step, these results are then checked for their common intersection. For this purpose, the principle of the Minimal Viable Product (MVP) can be applied to ensure that methods cover the areas of Lean Management and Six Sigma equally in the best possible way. Hereby an increase in value, due to the versatile application within the individual quality management systems of the selected methods, is to be created. [40] In the following step 1.2 creation of selection criteria exemplarily the complexity of the use is consulted as a criterion. The Excellence Toolbox [41] serves as a basis, which is supplemented around the view of the job, processes or data. This is necessary to further specify the quality method selection and to better evaluate the application potentials for VR/AR. Once a selection of methods has been made for implementation, the aspect of the most interactive possible application of the learning environments is taken into account in addition to the goal of sustainable knowledge transfer to design the immersive portion of the training as much as possible.

ARIM – Design phase

Phase 2, the design phase, can be subdivided into conceptual preparations regarding technical, didactical and validation, which is reflected in the individual sections. Section (A) includes planning the virtual learning environment (VLU) of AR/VR as well as the didactic integration, as well as dealing with the technological acceptance. Under section (B), the training design is to be conceived. As another specific feature, the design phase in content creation features the application of the evolutionary prototyping process [42], whose testing and evaluation character is represented by the circles in fig. 2. In combination with the specific tests, the requirements of the users can thus be constantly specified and verified.

Within the design of the virtual learning environment (A), the instructional principles as well as the requirements for hardware, software, context of use, degree of reality as well as interaction and navigation mode should be dealt with. [11, 43] Basically, a distinction should be made between two scenarios - firstly, an entry scenario should be provided for learning, testing and orientation within the virtual learning environment, and secondly, a virtual training scenario with a focus on quality method teaching. The entry-level scenario should be optional and should be seen more as an additional offer that is intended to appeal to users who do not yet have much experience with the technology. The introductory scenario helps to reduce the cognitive load for operation, to counteract any motional sickness that may arise, and to reduce

inhibition thresholds in use. By those means it is then possible to focus better on the content-related task of the respective quality method in the training scenario. To be able to analyze the technological acceptance (A), the Technology Acceptance Model (TAM) according to Davis [44] is used and extended by essential items in connection with VR/AR [45], like cognitive load or also motion sickness. [46 - 48] The goal is to achieve an adaptation of the TAM to an immersive focus. This adaptation and the associated query of acceptance must be validated separately, e. g. in the form of questionnaires based on the TAM 3 [49] or UXIVE Model [50]. Under the didactic design (A) counts among other things the argument with the aspects of learning-theoretical frameworks, learning methods, learning contents, learning types and teaching forms.

The conceptional training design (B) can be further divided into two areas - one for VR/AR preparation and one for validation preparation. VR/AR preparation includes the creation of a guide for the users and the provision of VR/AR glasses. The latter includes, among other things, playing with the virtual learning environment, issuing access authorizations and taking out the necessary insurance policies, as well as an overview of standardized hygiene measures. The guide is intended to serve as an aid and provides information on basic instructions, the hardware itself, setting up the VR/AR glasses, the procedure, starting the virtual learning environment, cleaning and packaging, and contact options. The planning for the execution of the evaluation includes the creation of a questionnaire as well as a schematic procedure, which also covers aspects like the acquisition of the participants with the collection of the previous knowledge and the organization of the training framework. The creation of the questionnaire contains the partial steps 1. Preliminary work, 2. Questionnaire production, 3. Execution, 4. Results and afterwards 5. Evaluation. [51 - 54]

Step 1: Preliminary work deals with the structure of the questionnaire, e.g. number of categories and questions, type of questions (closed, semi-open, open questions), free text options, or scale levels. In sub-step 2. Questionnaire design, the advantages and disadvantages of an analog and digital questionnaire should be weighed up, as well as their access or distribution options. According to this decision, sub-steps 3 to 5 are to be adapted and open questions are to be clarified, e.g. whether further aids such as tablets are necessary or not. The design phase thus serves a material design for the VR/AR learning environment. The creation of a VR/AR learning environment maps an iterative development process that is also to be validated iteratively through various usability tests. These can be divided into four types: exploratory, assessment, validation, and comparison tests [35], see fig. 2. Possibilities for implementation include questionnaires, group discussions, video analysis, observations, thinking aloud, and

various forms of interviews. [55] Each specific test is again aid for the further elaboration of a scenario. That means at the beginning a first, simple test scenario is to be compiled, a so-called "rudimentary prototype", which can be optimized with the help of the exploration test in the follow-up. Only a small number of test subjects is necessary. [35] After successful testing and implementation of individual functions, a "final prototype" for quantitative data collection should be tested with the help of so-called assessment tests. Through the subsequent validation test, initial testing takes place in the entirety of the virtual learning environment in the targeted training framework. This early testing, subsequent improvement and its repetition avoid costly errors and costly correction loops. This represents an iterative approach. In the long run, comparative tests can be used to verify sustainable knowledge transfer.

Phase 3, validation, focuses on the design of practical implementation. Here, with the help of a validation test, the entirety of the AR/VR learning environment in the training framework is to be carried out for the first time, tested, evaluated and assessed. The validation test resembles the quantitative evaluation, so a higher number of learners to be interviewed, about 20 participants and more, is necessary. [56, 57] The results should give conclusions about the acceptance as well as improvements of the virtual learning environments and the holistic view of the ARIM.

ARIM – Potential analysis in practice

The development of ARIM, which enables the flexible use of VR/AR, is being tested for its applicability and completeness in the WILLEN research project. The background to the creation of VR and AR training units is to link attendance phases that are as compressed as possible in a continuing education institute with teaching units that can be attended flexibly online and from home. The project aims to promote sustainable continuing education through the use of technological assistance systems. Further education and thus also the qualification of persons should be better compatible with operational and family conditions. Specifically, the potential analysis phase was currently carried out in the project. In the first sub-step of the potential analysis, an overview of quality methods from the area of Lean Management and Six Sigma was created. Thereby extensive literature research as well as an analysis of existing training series and further education offers took place. The first result was an overview of 68 quality methods, which were examined in the next step for their synergetic application within Lean Management and Six Sigma. According to the MVP principle, 12 quality methods have been identified as a common intersection. These include the quality methods of:

- Brainstorming

- Failure Mode and Effects Analysis (FMEA)

- Flowchart

- Ishikawa – diagram

- Cost-benefit analysis

- Plan-Do-Check-Act phases (PDCA)

- Poka Yoke

- Process documentation

- Prozess mapping

- Supplier, Input, Process, Output, Customer (SIPOC)

- Swimlanes

- Value stream mapping

In the second step of the ARIM potential analysis, it should be possible to evaluate a VR/AR implementation concerning the generation of added value by creating selection criteria. For this purpose, 13 criteria are used. The criteria

- Organizational techniques

- Behavioral Techniques

- Purpose

- Graphic result

- Required qualification

- Impact on the quality

- Complexity of use

- Time required for implementation

are based on the Excellence Toolbox, see ARIM potential analysis. The original criterion possibility of execution by only one person was adapted to solo or team work. Furthermore, the criteria were supplemented with additional quality method-specific criteria. Thus, in the following criteria are to be applied: Organizational techniques (1), technology evaluating techniques (2), behavioral techniques (3), purpose (4), presentation of graphical results (5), required qualification of employees (6), impact on the quality (7), focus on the process (8), data (9) and workplace (10) as well as complexity of use (11), time required for implementation (12) as well as the criterion solo or team work (13). An excerpt of these can be seen in table 1. The entire table can be found at [58].

Table 1: An excerpt of the selection of quality methods according to criteria (ARIM - Step 1.3) | own illustration

No.	Criteria	Brainstorming	Failure Mode and Effects Analysis (FMEA)	Flowchart
1	organisational techniques	◕	◕	◑
2	Technology evaluation	○	◕	◔
3	Behavior techniques	○	◑	◔
4	Purpose	- Decomposition - Grouping - Pointing out relationships - Creative techniques of teamwork	- Decomposition - Grouping - Flow description - Process variation analysis - Analysis of process accuracy - Classification and labeling of critical elements - Identifying relationships - Management of goals/changes	- Decomposition - Grouping - Flow description - Analysis of process variation - Pointing out relationships
5	Graphical result	map, sheet	matrix, table, list	sheet, map, diagram
6	Required qualification	◔	◕	◑
7	Impact on the quality	S, M, L	M, L	S,M
8	Focus process	○	◑	●
9	Focus data	○	◕	◔
10	Focus workplace	○	○	○
11	Complexity of use	◔	●	◑
12	Time required for implementation	◔	◕	◑
13	Solo- or team work	(SW) TW	SW, TW	SW, TW
	Index	17	37	27
	Conclusion			
	Potential for VR	no	yes	no
	Potential for AR	no	yes	no
	Legend: Harvey Balls: Experience-based evaluation of the respective criterion; S = short term, M = medium term, L = long term; SW= Solo work, TW = team work			

Organizational techniques are understood as the systematic approach to designing organizational structures. The criterion *technology evaluating techniques* represents the approach to improving production and service processes based on statistical, data evaluating procedures. *Behavioral techniques* are about the impact of employees on the overall organizational structure. These three criteria serve as an overview in which areas the quality methods are used and whether specific requirements for the realization in VR/AR can be derived for the design phase. The *Purpose* criterion has the following sub-aspects:

Decomposition, Grouping, Flow Description, Analysis of Process Variation, Analysis of Process Accuracy, Classification and Labeling of Critical Elements, Showing Relationships, Management of Goals/Changes, and Creative Teamwork Techniques. This allows a specific grouping of the quality method. The information of the *graphical results* should give an overview of the type and manner used in presence. This includes the use of the types diagram, map, matrix, table, list and sheet. The classification provides orientation as to which means are necessary for VR and AR respectively which aspects should be paid attention to during the realization. It can also provide an initial assessment of the effort required for implementation. The criterion *required quality of the employees* can be classified from low to very high. This allows conclusions to be drawn about the requirements for VR/AR implementation. For example, if a very comprehensive qualification is required, the implementation in VR should either be as simple as possible, with little potential for distraction, or implemented with different user levels. For example, when using different user levels, in VR the learner could choose a level between Novice, Advanced, and Professional at the beginning. The Novice level could, for example, work with further options, an additional instruction text or support functions. The professional level, on the other hand, could be designed to be more streamlined. The criterion *impact on the quality* is divided into short term, medium term or long term. This is the effect of the quality method used, how quickly an improvement can be determined and thus the quality of, for example, the processes can be optimized. The criteria *focus on process*, *data* and *workplace* help to gain an overview of the areas in which the quality methods are used. This classification of the last four mentioned criteria gives a specific overview of the quality methods and thus enables prioritization of the VR/AR implementation, e.g. if a balanced mixture of the presented areas is aimed at. Likewise, the expenditure of the realization can be better estimated. If, for example, only the workplace is considered, this can mean less effort in the implementation compared to a holistic process consideration, which consists of many steps and thus becomes more complex in the implementation. The criterion *complexity of use* describes the degree of difficulty of the method. The *time required for implementation* is clustered into low to very high. Thereby low counts as an effort of a few weeks to 2 months, medium the time consideration of >2 - 6 months and very high a period of 12 months or longer. This time expenditure gives an orientation of the complexity and thus also of the effort of the implementation in VR and AR. The last criterion *solo-* or *teamwork*, enables the classification of the quality methods in the degree of collaboration. For example, if the quality method represents pure teamwork, it is necessary to consider how it can be represented in VR. Is an interactive application possible through the sole use of VR glasses, can the virtual learning

environment only be used in multiuser mode, or is a VR cave required are just a few clues that must then be clarified in the design phase.

An overview of sub-step 3. selection of quality methods according to criteria can be seen in figures 2.1 and 2.2. The individual criteria were evaluated in two systems: firstly via Harvey-Balls as a 5-level scale [59] (criteria 1-3,6,8-12) and secondly via quantitative enumerations of possible results of the respective criterion (4-5, 7, 13). The index is a relative classification of the methods to each other about their extent and applicability to the evaluation criteria. It can be used as an orientation for depth, scope, complexity and effort in the implementation of a virtual learning environment for the respective method, even if it does not make an explicit statement about it. The index forms the quantitative sum of the results of all evaluation criteria of a method, adding the scale of Harvey balls with the sum of the result enumerations of criteria. A maximum index value of 56 can be achieved. So that a realization in VR/AR should be aimed at, an index value of at least 28 or greater is reasonable. The minimum score of 28 ensures a quantitative implementation of the method in VR/AR, so that a sufficient minimum coverage of the criteria is fulfilled.

In table 1 it becomes clear that not all quality methods standing to the selection are meaningful for the desired realization and thus no further consideration is given. Particularly with the method Flowchart, it concerns a schematic representation of function modes, processes and programs and with the method process documentation mainly around the documentation of the won realizations, so that after today's state of the art writing in real-time within the VR is problematic. [60] This challenge can cause a disruptive factor within VR, which can frustrate and demotivate the learner. In the context of an accompanying cognitive overload, the realization should be critically considered whether the added value is enabled by the VR application or whether a different form of representation is appropriate. In contrast, the Swimlanes method, which considers processes across departments, is seen to add value in the implementation of VR, contrary to the evaluation. VR offers a high potential to represent different and complex scenarios, which in reality may be significantly more costly to represent in terms of space, resources, etc. If this method is now added, there are 8 quality methods to choose from for the AR area, and 9 quality methods in the VR area. These are

- FMEA
- Flowchart
- Ishikawa
- Plan-Do-Check-Act phases (PDCA),

- Poka Yoke

- Process documentation

- Supplier, Input, Process, Output, Customer (SIPOC)

- Swimlanes

- Value stream mapping

The last sub-step 4. selection of assistance systems provides an overview of the manufacturers and the necessary information such as costs, video quality/resolution, display resolution, field of view, weight, software, type of navigation, battery capacity, tracking options, availability of hardware and in the area of VR the criterion of degrees of freedom. Due to the requirement of self-sufficient use, standalone VR glasses are targeted in the VR domain so that self-paced, interactive learning is encouraged among participants with minimal hardware requirements. This requirement significantly limits the choice of possible vendors, so two systems were available for selection. Considering the initial cost, the Quest 2 system from Oculus is used. A standalone variant always poses a challenge about the available polygon capacity of the display, so after the decision of the hardware basis, the selection of the quality method and its complexity must be checked again, taking into account the selected hardware. The degree of complexity is reflected in the effort of creation, which can also be quantified in costs. This is to be brought in connection with the immersion possibility. The classification, which was discussed and confirmed in the context of an interdisciplinary consortium, can be seen in figure 3.
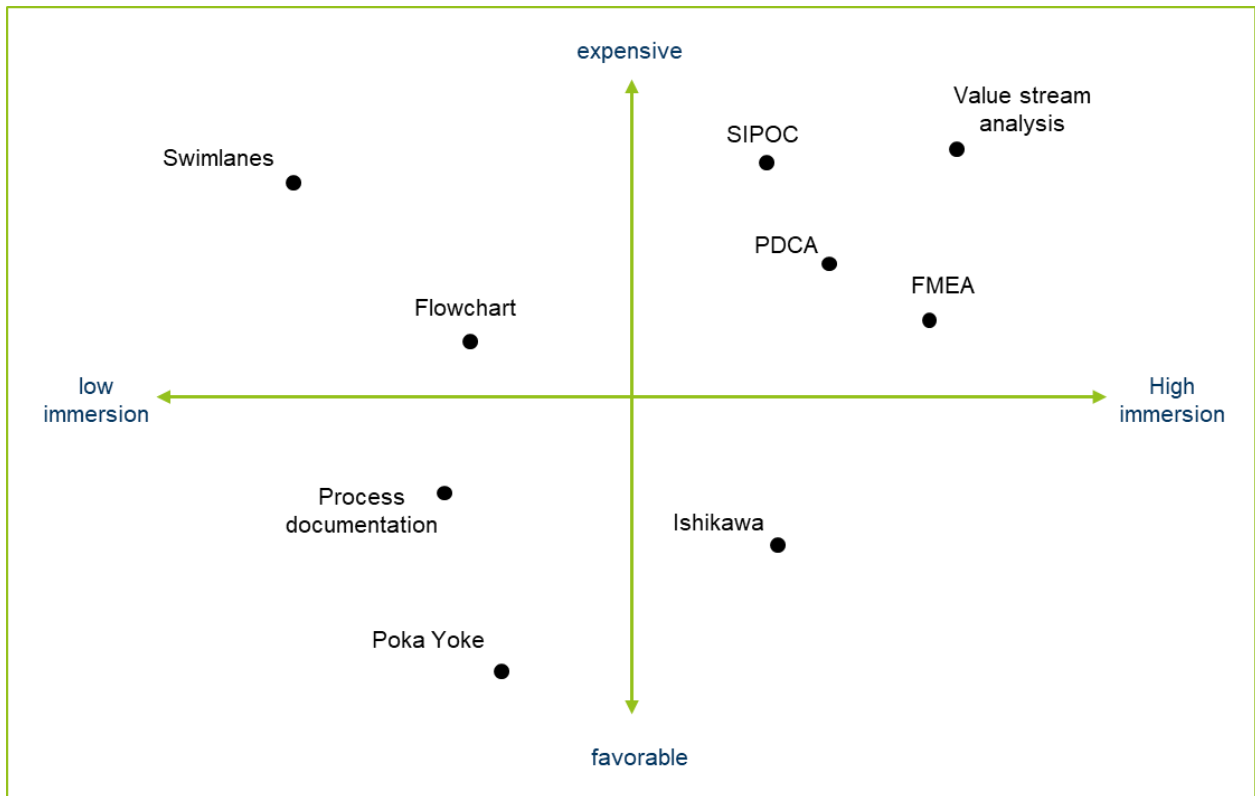
Figure 3: Cost-immersive utilization analysis of quality methods | own illustration

For a further delimitation for the concrete conversion of the quality methods the Define - Measure - Analyse - Improve - Control (DMAIC) cycle of the Six Sigma is consulted. [61] To achieve a balanced application of the individual quality methods per DMAIC phase, it is recommended the 5 methods Ishikawa, FMEA, Swimlanes, SIPOC and PDCA, in the focus of the potential realization lie. Each of these methods can be assigned to a respective phase. The exact design and requirement for the realization should be gone through in the subsequent **ARIM design phase** with its sub-steps.

Summary and future work

The training of quality methods with the help of AR and VR glasses is a promising field of application that has received little consideration in research and industry today. Digital assistance systems for training purposes offer many advantages compared to traditional face-to-face events, such as time independence of the training for the participants. To address the emerging need for research, the Assisted Reality Implementation Model (ARIM) was developed. For this purpose, the potential analysis contained in it has already been successfully carried out. In the process, a comprehensive overview of potential quality methods was created. Based on the selection criteria for the VR/AR realization as well as the technical requirements,

this overview could be narrowed down in a meaningful way, so that a certain selection of quality methods for the virtual learning environment could be focused on. These include the Ishikawa, Plan-Do-Check-Act, and Failure Mode and Effects Analysis quality methods. The next step is to implement the design phase of the ARIM. In the realization of the virtual learning environment, the aim is to make the interaction as intuitive as possible so that it can be used by participants in everyday life without much additional effort.

Statements and Declaration

Declarations

Conflict of interest The authors declare that they have no confict of interest.

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