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Vocational Training with Microlearning – How Low-Immersive 360-Degree Learning Environments Support Work-Process-Integrated Learning

Matthias Billert*, Tim Weinert*, Marian Thiel de Gafenco, Andreas Janson, Jens Klusmeyer, and Jan Marco Leimeister

***Abstract*— In-company training is facing new challenges in preparing employees for the demands of digitalized and automated manufacturing. New training concepts like microlearning are necessary to support work-process-related learning. To handle the limitations of microlearning, we develop a 360-degree learning system to demonstrate a realistic work environment. Nonetheless, there is a lack of design knowledge supporting the motivation and performance of employees using the system. Based on a systematic literature review and semi-structured interviews, we have developed design requirements for interactive 360-degree learning environments. We used a workshop-based mixed-method approach with interviews, concept maps, and video analysis to evaluate the motivation and performance of precision mechanics within a prototypical work-process-oriented learning environment in an inter-company vocational training center. The results show a positive effect on learning outcomes and motivation. In addition, the ease of use and sense of presence while using the learning environment are rated as high. We contribute to theory by shedding new light on learners' motivation and performance within work-process-oriented interactive 360-degree learning environments. Furthermore, we offer guidelines for developing such interactive 360-degree learning environments.**

***Index Terms*— Virtual Reality, Interactive 360-Degree Images, Motivation, Engagement, Performance, Learning Environments, Work Process Simulation**

I. Introduction

INCREASING digitalization and automation of manufacturing processes is shifting the demands on employees' skills and knowledge [1]. Simultaneously, a decrease in the half-life of knowledge can be observed, which increases the need for continuous training of employees [2]. Companies respond to this development by expanding their in-company training offers, particularly through the development of digital learning opportunities like microlearning. Work-progress-integrated learning plays a major role in supporting employees in gaining action-oriented knowledge [2]. However, the transfer of practical, action-oriented knowledge, such as the operation of industrial machines, presents a huge challenge in manufacturing because learning often has to take a back seat, and the work process is given priority [1].

One possible solution to overcoming these challenges is the use of virtual learning technologies to build realistic work-process-oriented learning arrangements [3]. Virtual reality (VR) enables the creation of 3D environments in which one can navigate and interact with things [4] by manipulating objects or exploring the features of an environment. This allows employees to learn necessary skills and knowledge within their work environment while being involved in the actual work process. While there is a wide range of different approaches to creating VR environments, many companies are deterred from developing such learning environments because the initial development and adaptation of the VR environment is costly [5]. A way to overcome these problems is the application of 360-degree pictures. With 360-degree cameras, it is possible to enrich learning situations by capturing realistic and immersive images [6]. The resulting 360-degree images in turn enable learners to be situated in the working and learning environment and, thus, be more actively involved in the learning process [7, 8].

Due to their much simpler development (in comparison to complex VR environments) these 360-degree learning environments could be suitable as a solution to the acquisition of action-oriented knowledge in manufacturing—the lack of completeness of the action. The rapid change of knowledge in production requires new concepts for the development and transfer of knowledge. An increasingly employed concept is that of microlearning, which consists of small learning units to

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support the acquisition of competencies in the work process [9]. Microlearning enables the transfer of expert knowledge, as it is integrated into a concrete situation and is not explicitly and formally designed [10]. Currently, there is a lack of knowledge regarding the integration of such VR learning environments in working processes to support the acquisition of action-oriented knowledge [11]. Anecdotal evidence from industry partners suggests that the lack of interaction in traditional learning environments could be solved by the implementation of interactive elements to integrate microlearning and the creation of a work-process-oriented 360-degree learning environment. As a result, companies have no knowledge of how to support the motivation and performance of their employees within the training and learning process in 360-degree environments. Moreover, due to the cost and effort involved in developing VR systems, many companies balk at purchasing such interactive learning systems. Based on these challenges, we aim to answer the following research question:

How must an interactive 360-degree learning environment be designed in order to support the knowledge acquisition of learners in the training and learning process?

To answer the research question, we derived requirements from a systematic literature review and interviews with learning service providers for the design of 360-degree learning environments. Finally, we developed and evaluated the system within three design iterations in an inter-company vocational training center as a web-based learning environment.

II. Related Work

A. 360-degree learning environments

A 360-degree picture is recorded in every direction simultaneously, resulting in a realistic, full environment that a person can experience from a camera's point of view while being in control of the viewing direction [12]. The resulting picture can be viewed on a monitor or with a head-mounted display (HMD) [13]. A user can control the view of the picture with the movement of their heads, their monitors, or by using the mouse or touchpad. According to Milgram [14], 360-degree pictures can be classified as a kind of VR. These VR environments can be described by their immersion and the presence they provide [4]. The higher the immersion, the more the user can interact with the virtual environment (i.e., see, hear, or touch). High presence is achieved when users, despite knowing that they are in a virtual environment, feel present in the environment and respond realistically to a situation they experience in the VR [12]. Thus, presence is a subjective construct and is associated with the individualistic perception of the user. Therefore, different users will discover different levels of presence in the system, while the immersion in the system will be the same [4, 12]. As mentioned in [4, p.4], a "well-crafted virtual world could change our emotional state and make us feel anxiety, happiness, or sadness". That VR worlds exert these effects on people can be confirmed in different contexts, i.e., in bullying prevention [15], or in trainings of mechanics [3]. Furthermore, the possible interactions within the 360-degree environment enable an active evolution in the learning process rather than the passive role taken when viewing traditional pictures or videos [16]. Although we have focused on a low-immersion, monitor-based 360-degree learning environment, the question is how this environment needs to be designed to promote presence within it, with the goal of promoting situational engagement with learning materials in work processes.

B. Situated Learning and Microlearning

Through the increasing demand for in-company training, new concepts are necessary to fulfill the requirements of high-quality trainings within working processes. One concept increasingly being used in production and coming into scientific focus is microlearning [17, 18]. Microlearning consists of small learning units that often cover a single topic and are limited in length [19]. These small units can be consumed quickly and are created in the interaction between humans and media technologies [19]. The inclusion of the learning context in the learning materials offers an advantage in the learning process because knowledge can be situated and is manifested in daily activities [20, 21]. Conventional learning materials have the disadvantage that the content often has to be concretized to the application context of the employees. This requires additional cognitive effort, which reduces the employee's ability to process the learning content [22]. Due to the small-scale structure of microlearning, it can easily meet learning needs in a fast-paced work environment, as it can help employees learn a specific and actionable task [9].

However, microlearning is also criticized because the small-scale structure does not necessarily follow a didactic sequence, and thus complete work process procedures can hardly be mapped [9]. Because of the need to map a complete work process, the connections between individual microlearning elements are often lacking. This is precisely where 360-degree images can help and provide an interactive way to connect individual microlearning elements in a real-world VR environment. Individual microlearning elements can be used in the form of interactive elements within the work environment to simulate a typical workflow. Such interaction possibilities are often lacking in digital learning environments due to the missing connection to the working processes of the employees. VR environments can support these interactions by mapping them directly onto the work process [23].

Nevertheless, it is still unclear how such VR environments have to be designed in order to foster interactions during the learning process and how they can support the usage of microlearning. Therefore, we aim to create an interactive, 360-degree work-process-oriented learning environment based on the current state of research and practice.

III. Requirements for 360-degree learning environments

To develop interactive 360-degree environment, we used a rigorous theory-driven approach and derived and analyzed existing knowledge about interactive images and 360-degree images from within the literature and practice as a first step. To identify theoretical requirements, we conducted a systematic literature review according to Webster and Watson [24] and vom Brocke et al. [25]. The review aimed to find dimensions, frameworks, instructions, and information that show how interactive 360-degree images can be created to support the learning process. A short summary table of the literature review process can be seen in Appendix A.

To complement the knowledge from theory, we followed a user-centered design approach. As a start, and to create a common awareness of the problem, we conducted semi-structured interviews with five experts from German digital learning platforms that already have existing VR systems in use. The interview guideline consists of seven questions and each interview lasted between 21 and 45 minutes. One person is female, four are male. For more information about the interviews, please refer to Appendix B.

We derived five requirements for the design of our 360-degree learning environment. These requirements and derived user stories are shown in Table I and will be described below.

The design and implementation of VR environments is typically a complex approach. Makransky and Petersen [26] describe a theoretical model to support developers of immersive VR learning environments. However, the CAMIL framework presented focuses heavily on user immersion, while our approach focuses on a more low-immersion environment [26]. In general, a VR learning environment offers the possibility for users to move independently within the environment [27]. This independent organization of the learning process has positive effects on motivation, engagement, and curiosity [27, 28]. At the same time, users can be supported in this independent discovery and organization of the learning process, since they usually do not have the necessary skills and knowledge to manage the process on their own [29]. Additionally, the 360-degree learning environment should provide a guiding structure that helps learners with hints and suggestions for planning the next steps in the learning process (Req. 1).

Schweitzer et al. [30] reported that unstructured interaction elements within their application has restricted the ability to concentrate on the learning process [31–33]. Consequently, we suggest supporting users by using scaffolding elements to provide assistance with the usage of the interaction elements in the environment [34] (Req. 2.).

When using new technologies, usage errors or questions may arise, which can be reduced but not completely avoided by a rigorous design and good structure. Furthermore, the learning process itself can be challenging for the learners. In traditional learning approaches, teachers and other peers provide feedback, corrections, and guidance [33, 35]. Through the collaboration and interaction between peers and teachers, the acquired knowledge is consolidated and internalized [29]. Consequently, we include feedback elements in our 360-degree learning environment to support the users within the learning process (Req. 3).

Because of the limited cognitive resources of humans, IT artifacts must be designed in such a way that a cognitive overload is avoided [36]. This observation can be applied to learning contexts, as the cognitive abilities of employees are challenged in these situations. In work-process-integrated learning, special attention must be paid to these limitations, since the learning process takes place during work [37]. The unnecessary search for functions, unclear symbols, or the prerequisite of a certain level of knowledge can further complicate the use of the application [32]. For example, Xie et al. [32] developed a simple tool bar to give an easy overview of the main functions of their learning platform. A simple and clear UI can be a key element in improving the usability of the platform [30] (Req. 4).

In this digital era, many technology approaches can be used to design a 360-degree learning environment [29]. These different technical solutions enable the development of highly complex VR environments, i.e., highly immersive learning environments to support conversations [38], do earthquake emergency training [39], or train blue-collar workers [3]. However, adding more and more complex elements and functions increases the effort required not only for the development but also for the use and familiarization with these systems. Wästberg et al. [29] recommend striving for the simplest possible design, which fulfills the requirements of the use case and provides the right degree of realism and accuracy for the intended target group (Req. 5).

TABLE I
REQUIREMENTS AND DESIGN ELEMENTS

Requirement and derived user story	**Derived design elements**	**Element description**	**Source**
As an employee, the learning process must be structured so that I can integrate it into my work.	Creation of a comprehensible structure	Provide a main structure within the 360-degree learning environment to help learners organize their own learning experience.	[27, 29, 34]
As an employee, I need help with the learning environment, especially when things get a little more stressful and I'm short on time.	Scaffolding elements	Provide scaffolding elements to enhance users' understanding of the learning material.	[8, 27, 29, 30, 31]
As an employee, I need to be able to communicate with my colleagues or with my superiors when I get stuck.	Feedback functions	Provide feedback elements to support users when using the 360-degree learning environment as well as the learning process.	[27, 29, 35]
As an employee, I want to be able to quickly understand how to use the learning environment without having to go through a complicated learning process.	Simple and Clear UI	Provide a simple and clear UI to avoid a cognitive overload within the usage of the system.	[29, 33, 35]
As an employee, I would like the learning environment to realistically reflect my workplace.	Adequate degree of realism	Select the easiest application that fulfills the requirements of the use case and provides the right degree of realism and accuracy to the intended target group.	[29, 32]

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IV. User-centered System Development

For the iterative and user-centered development of the interactive 360-degree environment, we focus in this section on the design considerations of the technical architecture and describe the iterative development process.

A. Technical Architecture

The technical architecture of the 360-degree learning environment uses an existing panorama viewer for the web (Pannellum[1]) so that the 360-degree images created by the GoPro Max[2] can be displayed (1–2). The GoPro was installed on a trolly and moved through the manufacturing rooms to create a room tour where users could move freely. The customization of the Pannellum environment is performed with the HTML5 markup language, CSS stylesheet language, and JavaScript scripting language by using the developer environment WebStorm by JetBrains[3] (4). For a local instance, Pannellum requires a server application (3). All tracking records were made using Matomo[4] (5). An overview of the setup process of the 360-degree interactive environment with the technical architecture is summarized in Fig. 1.

The development process of the 360-degree learning environment is divided into three iterations with accompanying evaluation workshops in the manufacturing facilities of an inter-company training center over one and a half months [40]. The development process and the adjustments in the iterations of the system can be seen in Fig. 2. We begin by describing the initial design of the system and the adjustments we made to the technical architecture.

Following the suggestions of El Kabtane et al. [41], we changed the object status by using different shapes and background colors for our buttons. For triggering an animation, we placed a button that added or removed an impulse on all buttons (blob function). The learning content is placed in modules, which appear after clicking the associated button.

To create a uniform style [30], we developed the interactive 360-degree learning environment in a highly interactive way by offering a clickable and explorable environment with parametric changes (scenes, buttons, colors, information) in real time. It was also possible for the learners to stop or reverse an operation by clicking the same button again (e.g., the animation button). We focused on the single graphic concept by integrating graphical information in HTML modals. All elements and interactions are based on familiar, everyday elements such as color combinations, numbers, and intuitive handling such as pressing, swiping, etc. for an easy and fast operation. Learners had to make the decision to start directly or to read helpful information first.

Using the design considerations for virtual labs [29], we formulated our vision as "Building interactive 360-degree images in the training and learning process" in order to be clear about the purpose and context of use. To account for the faithful appropriation of the learning environment [42], we implemented a description that highlights possible affordances on how learners can interact with the 360-degree pictures. This is especially relevant for deploying the learning environment in workplace learning, when learners, e.g., retrainees, are less experienced with such rather novel technologies. We implemented a description about what can be interacted with for learners with less experience in media consumption. In the beginning, we determined that our virtual lab is a realistic 360-degree learning environment for optimizing training and working processes. In addition, we adjusted the degree of realism by implementing panoramic and spherical images of real working environments.

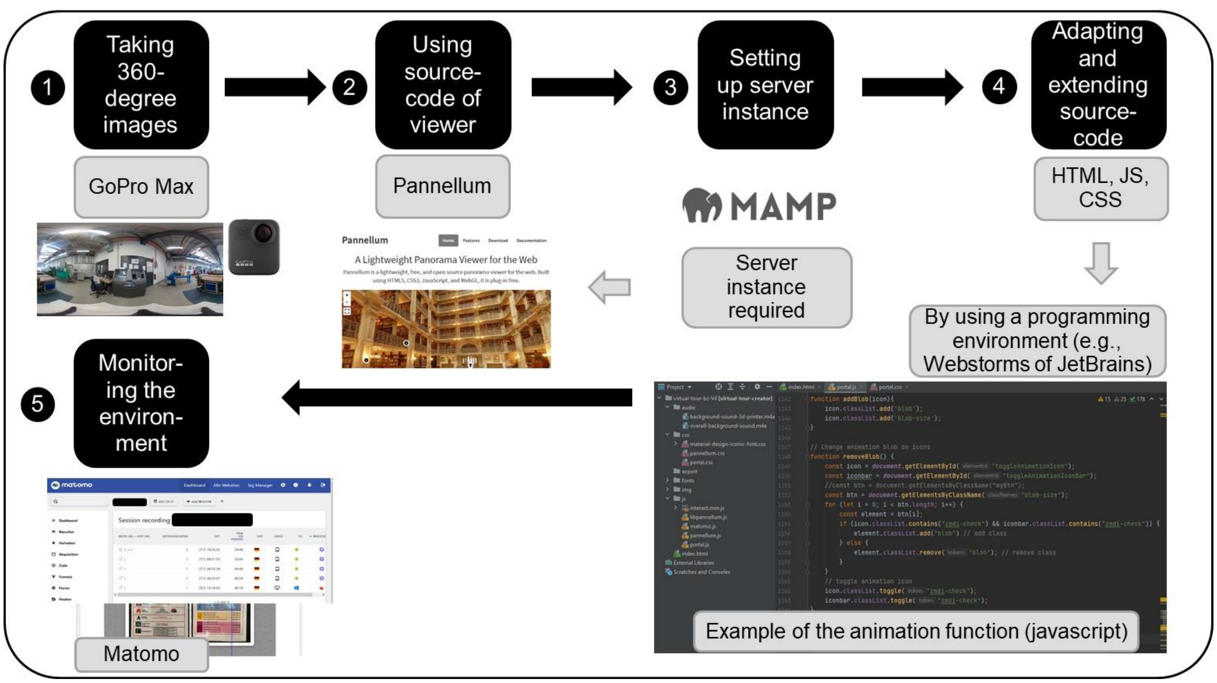

Fig. 1:Technical architecture of the 360-degree environment

[1] https://pannellum.org/
[2] https://gopro.com/
[3] https://www.jetbrains.com/webstorm/
[4] https://matomo.org/

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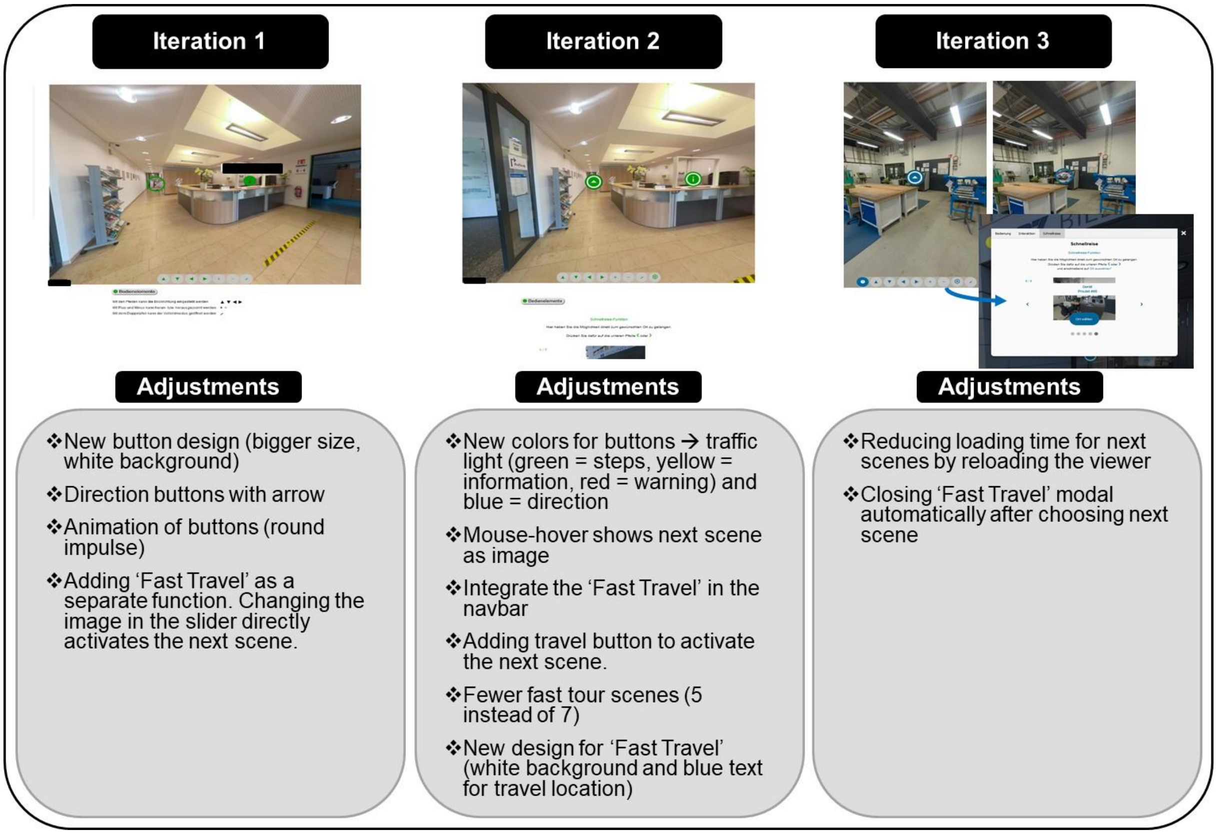

Fig. 2: Iterative development of the system

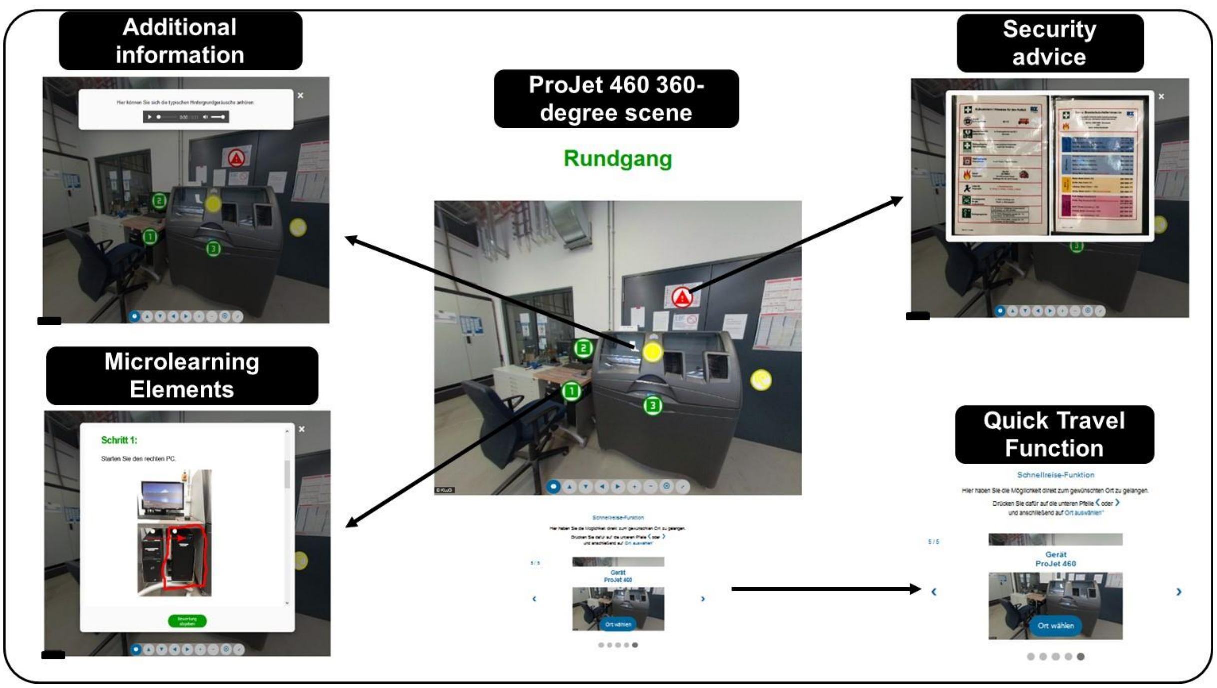

Fig. 3: Final version of the 360-degree learning environment

To develop a responsive learning system, we provided an internet-dependent and device-independent application for smartphones, tablets, and computers [43]. The application's design was continually customized. The learning content was organized by individual steps and based on a knowledge database.

Using the design principles for effective teaching material [11], we used suitable easy-to-use colors for comfortable handling. The control buttons are based on typical visual controls of 360-degree viewers with zooming, rotating, and full-screen functionality. In addition, we enabled learners to create their own learning process by providing different features within the interactive 360-degree learning environment, such as the travel function. To improve the learning experience, we implemented visual, auditory, and directive elements. progress bar in the form of selectable learning scenarios within the travel function. In addition, during the intervention, learners were free to structure the flow of the task and to explore the 360-degree learning environment independently. While we implemented buttons with different interaction tools (e.g., information pop-up or opening a microlearning element), we also created a linear sequence of tasks to convey sequential process information by using unique step numbers starting with one.

Drawing on the screen design elements of Burset et al. [44], we took the graphic aspects into account as well by adapting the shape, size, resolution, and significance to the feedback and needs of the learners within the three workshops. This also applied to the typography with a focus on readability as well as position, proportion, and the elements of action (recognition, visual effects, sound effects).

Since the learners may also include retrainees, we followed Xie et al.'s [32] senior-friendly design by prominently placing the control bar in the middle of the screen and using a text symbol combination (buttons with mouse-hover text). We formulated clear instructions for using the different features and decelerated the functions and features with a clear text.

B. *Iterative Development*

In the *first iteration*, learners operated a 3D printer (ProJet 460) and used the interactive 360-degree learning environment to learn the procedure. In this environment, the microlearning previously prepared by a teacher was used and linked using a systematic submission process. The 360-degree learning environment that was developed offered learners the possibility of exploring the environment independently by clicking on a button with a preview image to get to the next scene. During the iteration, the users reported that they were familiar with the environment and that it was tedious to navigate to specific locations via numerous clicks. In addition, they would not know in which direction the scene change would take place, even though the button was placed there accordingly.

A critique that arose was that the buttons were quite small. For this reason, the buttons for the second iteration were adapted in design by making them larger, with a highlighting white background and an animation function (i.e., round impulse of the buttons). In addition, a quick travel function was implemented, which enables the possibility to take learners directly to the desired location via an image slider.

In the *second iteration*, learners had to complete the same task again, this time involving novices who were briefed by learners from the first iteration. Particularly those who already knew the tour found the quick travel function to be a sensible feature and a good addition. However, the users mentioned that the access to the quick travel function is cumbersome. Therefore, we integrated the function into a navigation bar [32]. The direct selection of the scene via the slider was criticized, which is why a travel function button was added to activate it. We added a new design for the explanatory texts (blue with white background) of the individual scenes to get a consistent, cross-system, and eye-friendly color style for the system [35].

Furthermore, the number of scene images was reduced from seven to five because the learners reported back that they would like to start either in front of the hall entrance or directly in front of the unit. The users suggested using traffic light colors (green, yellow, and red) for classifying the content. Thus, the color of the motion button was also adapted (blue). In the *final and third iteration*, learners created their own microlearning using the platform with the systematic submission process and optionally operated the 360-degree environment again. Here, we optimized the loading time and the lack of automatic closing of 360-degree pictures after selecting the quick travel function. Both were subsequently fixed by reloading the viewer and implementing a function for closing the modal window automatically. The final version of the system is shown in Fig. 3.

V. Methodical Aspects of the Evaluation

A. *Participants*

Nine participants in the three workshops contributed to the evaluation of the system. The participants are precision mechanics in the first to third year of their apprenticeship with an age range of 25 to 40 years. The workshops were of similar length, lasting between five and six hours. The participants were guided individually through the workshop because only a limited number of 3D printers were available. To prepare for the three workshops, microlearning elements were developed in a separate session with a trainer using an existing co-creation platform and then integrated into the 360-degree learning environment. A brief overview of the participants can be found in Table II.

TABLE II
Participants Overview

Work-shop	Learner	Age	Sex	Duration of interviews (min)
1	L1	40	m	23:29
	L2	33	m	17:04
	L3	34	m	16:27
	L4	28	f	11:38
	L5	25	m	12:23
	L6	27	m	11:04
	L7	56	f	09:06
	L8	37	m	10:06
2	L3 / L9	34 / 25	m / m	21:30
	L1	40	m	20:51
	L6	27	m	09:27
	L4 / L7	28 / 56	f / f	08:09
3	L3	34	m	12:47
	L4	28	f	10:42
	L2	33	m	10:05

B. *Evaluation Instruments*

The aim of our evaluation is twofold. First, *we want to evaluate the usability and handling of the system in the work process*. Second, *we want to measure the effect the usage of the system has on core learning outcomes, such as motivation, engagement, and learning success.* In the first workshop, we focus on the impact of the 360-degree learning environment as

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a short-term intervention, with the goal of investigating whether the system can purposefully support employees in learning well-defined work processes. In the second workshop, we want to identify aspects for the further development of our system, especially to increase the usability of the system. In addition, we want to examine whether employees were able to remember the work process and to what extent the system is used to repeat the activity. The third workshop focused on the question of whether the knowledge about the 3D printer could also be articulated and documented in the learning system by the employees.

To evaluate the handling and the usability of the system, we use a video analysis [3] and a think-aloud method [45] to optimize the usability and the handling of the system. Additionally, we measure the satisfaction, engagement, and learning success of the participants during the workshop through concept maps [46] and qualitative interviews [47].

1) Video analysis

Observation methods are used for an in-depth analysis of the learners' behavior and interaction during the learning process with 360-degree images [48]. During the observation process, the learners were filmed to allow for later video analysis of the results. At the same time, an observation protocol was followed by the observer. We followed the procedure suggested by Becker [48], which assigns a passive role to the observer who is thus not part of the activity. Observation represents a proven method in vocational training research of quantifying the learned work procedures in the work process [48]. To support our approach, we recorded the learning process in relation to the 3D printer with the system. To analyze our results, we followed the procedure of Pletz et al. [3], who developed a VR environment for training in the work process. Unlike our artifact, however, they use a fully immersive approach to train learners. Based on this, we divide our observations into three dimensions: *Errors*, *difficulties*, and *other anomalies*. *Errors* describe actions that are not performed, performed incorrectly, performed in the wrong order, or performed with an incorrect tool. *Difficulties* are characterized by the fact that they are directly related to an action with which the participant shows that he or she is stuck, for example, by asking the expert what to do next. *Other anomalies* are actions that do not fit into the dimensions above, e.g., comprehensible and permissible changes in the procedure.

2) Usability Testing and Semi-structured Interviews

For the usability testing, we used the think-aloud method according to Lewis [45] for evaluating our user interface design and specific features of the interactive 360-degree images to support the training and work process. During the usability test, all learners have to share their opinion vocally about elements, interaction points, settings, and content with regard to color, functionality, etc. During the think-aloud session, the learners repeated their actions and formulated their thoughts aloud. In addition, we used the usability criteria from Osman et al. [49], including asking for qualitative feedback on speed of scene movement, navigation, background sounds, terminologies, quality of scenes/images, text/voice description, and attractiveness. For evaluating specific features, we asked the following questions: *1) Do you understand the functionality of the feature? 2) How well does the feature work? 3) What do you particularly like or not like about it? 4) Which variations did you use and why?* (if two features were available) *5) How well does a, b, c of the feature work?* as well as *6) Where would you place the content on the image and why? 7) Who do you think should create the content? 8) Who do you think should create the linkage between the content and the image?*

In addition to the think-aloud usability testing, we conducted 15 interviews with the participants. Thereby, we used Pedroli et al.'s [50] guiding questions to measure the usability, the sense of presence, and the expectations of the learners. In addition, we followed Lichtenstein et al. [47] for measuring engagement and motivation. In general, there are different ways to measure the engagement of the employees [51, 52]. We used a qualitative measurement by conducting interviews, because self-reports can disrupt the learning process, physical sensors were not available and the sample size was too small for quantitative measurements [51].

To evaluate the effectiveness of the interactive 360-degree image in comparison to other Learning Management Systems, we used the qualitative questions of Çöltekin et al. [53]. To check whether learners have understood the purpose of these tools, we used the questions of Djenno et al. [54]. All guided questions can be found in Appendix C. For analyzing the qualitative semi-structured interviews, we followed the qualitative content analysis of Mayring [55]. Therefore, we transcribed the recorded interviews by using a selective protocol following the same procedure as with the learning service providers. This means that we only used the relevant parts that are useful to answering our research question.

3) Concept Mapping

Concept Maps [56] are drafted by the learners before and after interacting with the learning environment to gain insight into the cognitive learning progress in work-process-oriented knowledge acquisition. Following Ruiz-Primo and Shavlson's [57] design implications for concept map assessments, we do not provide structural or propositional information with regards to the learning content. The paper-and-pencil approach is chosen as the mode of response. By applying a holistic scoring rubric by Alfalah [58], we evaluate the concept maps focusing on three distinct map attributes: *comprehensiveness* to describe the breadth and completeness of the expressed knowledge, *organization* as an indicator for systematization efforts, and *correctness* as a degree of conformity with facts, known truth, and logic. For each attribute, three different performance levels (1 to 3 points) with their respective criteria for qualitative coding distinguish the maps' quality. Coding is carried out with MAXQDA, software for qualitative data analysis, with the attributes as categories and the performance levels as sub-categories. Eventually, the scored points are aggregated for each map (3 to 9 points) and within the two elicitation phases to contrast the learning progress before and after interacting with the learning environment. Two of the authors of this study acted as raters after establishing the coding consensus.

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C. *Evaluation Procedure*

To clarify the evaluation procedure, Fig. 4 provides an overview of the workshops. Each participant gets a method introduction at the beginning of each workshop. Thereby, the participants get to know the concept map method by using a simple example.

In the first workshop, the eight participants developed concept maps based on their previous knowledge regarding the switch-on routine of the 3D printer.

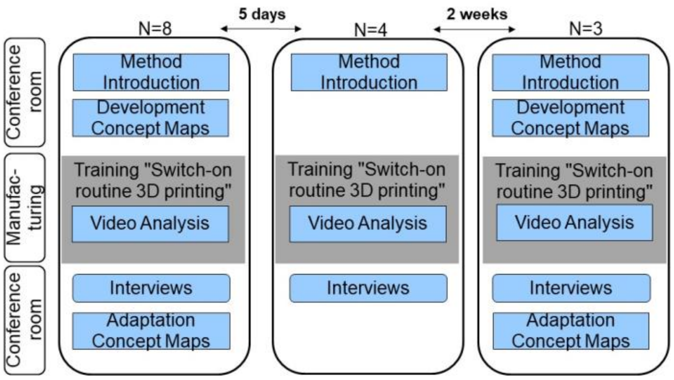

Fig. 4: Workshop procedure and study overview

Subsequently, the participants used the 360-degree learning environment to practice the switch-on routine of the 3D printer. The employees did not know this specific work process yet and we intended for them to learn the process by using the learning environment. A trainer was present to prevent critical mistakes that would have damaged the machine. The participants followed the work processes given in the 360-degree learning environment and the integrated microlearnings. During the work processes, the employees were filmed in order to uncover any problems or operating errors during the use of the system. As soon as the participants were able to carry out the setup process without any major problems, the training session was over. The employees were then taken through the structured interview to evaluate the usefulness of the system using the think-aloud method. At the same time, the motivation and engagement of the employees during the training were surveyed in the interview. Finally, the employees were asked to revise their previously developed concept map to verify the learning success of the employees.

In the second workshop, we followed the same procedure as in the first one, except that the participants have not developed concept maps. In the third workshop, we followed the same procedure as in the first one.

VI. Results

A. *Video Analysis*

The observation and video analysis took place over all three iterations of the system. A total of 15 observations were conducted in the training process of the employees. Subsequently, their behavior and interaction with the system were analyzed based on the three categories mentioned (errors, difficulties, other anomalies).

The first evaluation episode focused on getting acquainted with the system as well as the working process. Since the learners were not familiar with the system, the trainer had to intervene more often compared to the second and third iterations. In the context of the first iteration, the learners showed quite different learning tactics. One learner has intensively studied the developed learning environment and its contents in the run-up to the task (L1). Other learners used the learning platform during the work process and only read through the relevant passages that were important for the current step (L2).

Over the three iterations, it became apparent that the learner (L2) who read through the learning tasks in the run-up was able to solve the tasks in the work process in a better and more structured way than the group that dealt with the system and the work process simultaneously at the beginning. The reason for this could be the individual, intellectual grasp of the learners. Compared to the other learners, L3 made more mistakes and had more problems remembering the procedures in the work process.

The learners did not show any abnormalities or noteworthy problems in handling the system during the observation. Due to the changes to the platform over the three iteration steps, there was a certain degree of novelty in the use of the platform throughout, such that the learners had to get used to using the system again in some cases.

During the second iteration, it was found that all learners became increasingly accustomed to the work process sequence. Problems that occurred with the 3D printer were not related to the 360-degree learning environment but to the learning materials used. For example, two learners complained about the quality of the developed learning materials. In particular, they noted that the quality of the images used was too low.

B. *Usability*

In the first workshop, eight learners participated in the usability testing and the semi-structured interviews. During the usability test, the learners particularly emphasized the ease of use and comprehensibility (L4, L5, L6, L7). However, some learners (L2 and L3) mentioned that it would take quite a long time to run through the entire learning environment before arriving at one's own workplace. At the same time, learners emphasized that the initial familiarization with the work environment through the 360-degree learning environment was perceived as positive.

In the *second workshop* six learners and in the *third workshop* three learners conducted the usability testing including a rating of functionalities. During the usability test, only four sessions were recorded because two sessions were composed of a novice and a learner from the previous workshop. The novice was to watch the expert during the observation phase and then take over the main role in the interview to reflect the impression of the learning environment with support.

In this context, we have explicitly considered the following most-reported issues from the workshops: *quick travel function, animation function, and the design and functionality of the buttons.*

In session one, L3 and L9 mentioned that the *quick travel function* worked well. When changing scenes, neither of them

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were overloaded, nor they could find their way around directly. While for novices the travel function would be interesting, experts prefer the quick travel function. In addition, the information about the travel points is very small on the tablet, and there were problems because the scene was not loaded quickly enough. In the first version, the scene was loaded directly in the slider. This was a disadvantage if users only wanted to read the scene information and not travel there directly. Overall, learners were happy about the feature and were able to provide helpful feedback for optimization.

For the *animation function*, neither L3 nor L9 paid attention. L1 found it helpful and said the button strongly encouraged them to press, "press me". L1 did not discover the close function of the interaction pop-ups. He said after the hint that the function exists: "The function is there, better than if it were not there". L4 and L7 found the function helpful because they directly knew where to press on the image. Since there were no negative comments and the positive comments perceived the function as a support, the function can be considered helpful.

Regarding the *design and functionality of the buttons*, the learners (L3 and L9) found the additional information to be helpful. The safety-first information was important. The numbering of the steps was understandable and having an arrow indicate the direction was much better. Overall, the participants mentioned that the user interface had been improved, and the navigation through the environment had been simplified.

To increase understanding of the different interaction elements in the 360-degree learning environment, we adjusted the color scheme of the elements as described earlier. Overall, it shows that the design of the buttons plays a very crucial role and especially that the proposed color scheme represents something novel. In addition, we used Osman et al.'s [49] criteria to validate the usability of the 360-degree learning system, and found that they underline our results.

C. *Motivation*

To analyze the motivation and engagement of the learners, we used the guiding questions suggested by Lichtenstein et al. [47]. We assessed these factors during the first and third workshops.

The findings indicate a positive trend in terms of fostering motivation. Regarding the *motivation* of the participants, all participants mentioned that they feel motivated by the system. These statements were confirmed across the three workshops. At the same time, one participant noted in the interview that he has not wanted to participate in the test in the beginning, but he enjoyed working with the system. Therefore, it can be stated that the initial use of the system had positive effects on the motivation of the employees.

D. *Sense of Presence*

To measure the sense of presence, we evaluated the engagement, the perceived spatial presence, and the realism of the 360-degree learning environment [50].

Regarding the impact, the participants recorded that the 360-degree learning environment affects their engagement positively (see Table III). These statements (all translated from German into English) could be confirmed in all three workshops. In the interviews, we asked about the experience related to the piloting task ("How would you grade your engagement during the assignment and why?") and the specific experience of use of the system ("How has the system affected

TABLE III
EXEMPLARY QUOTES OF THE INTERVIEWS

Topic	Sub -Topic	Workshop 1	Workshop 3
Usability	Utilization	I didn't have any great difficulties. It was quite clear (L6). Had problems with the English terms in the control of the 3D printer. But generally everything was easily described (L5).	I got along quite well (L2).
	Learning	In the beginning I needed help. This was necessary mainly because I did not read the explanation in the material correctly (L4).	At the end I was confused and thought I was back at the beginning of the exercise until I realized I was seeing the summary. (L4).
	Pleasantness	Yes, I love this 360-degree environment (L4). Yes, in any case. Through the 360-degree view you have a 1:1 copy of my workplace, and you can orient yourself well (L1).	At the beginning I did not know what to click on. A little introduction would not have been bad (L3). No, I had no problems with the operation (L2).
Motivation		I was motivated because it was new for me (L1-L8). Yes, I was motivated. The motivation came from it being understandable. And when it works, it increases my motivation (L6).	Yes, I was motivated. Not at the beginning but later on I was (L2). Yes, I was motivated by the task (L4).
Sense of Presence	Engagement	The duration of the task was good (L1–4, L4, L6). I was happy that the exercise was over (because I was afraid of doing something wrong) (L3, L4–L8). I was very determined because I was interested (L4). Yes, I was engaged and wanted to know how the machine works (L3).	After the initial problems of understanding, the task was not difficult and proceeded quickly. (L4). The duration of the exercise could be shorter (L3). I had greater interest in learning something new through the system (L3). No through the system I was not more engaged than normal (L2).
	Realism	I find the 360-degree environment realistic (L1–L8). I feel like I am a part of the environment (L1-L8).	You can see all sides of the machine and the control. You don't have to run. It is very realistic (L4).
	Spatial presence	Feels like being part of the environment (L1–L8). Yes, I could relate to the environment (L4).	Yes, I felt like I was part of the environment (L2).

your engagement?"). In both cases, participants reported positive experiences with the task and the system. However, some learners mentioned that the new work task in combination with the new learning environment was very challenging after all. At the same time, they found it challenging to create new learning materials in the 360-degree learning environment, as such tasks are usually commonly handled by supervisors. Simultaneously, many of the learners also found these tasks to be an enrichment of their current tasks.

The perceived degree of realism, which can be affected by the immersion and presence of the 360-degree learning environment [59], was positively referred to by the participants in the interviews. All participants confirmed that they found the learning environment very realistic and therefore had no comprehension questions.

Regarding the spatial presence, the users mentioned that it "feels like being part of the environment" (L1). This feeling of being present in the environment is of particular importance for the learning process, as it enables users to locate the individual microlearnings more quickly in their respective workplaces. Comparing the first and third workshop, all participants responded similarly when asked if they felt like they were part of the environment. This is also relevant with regard to the introduction of the quick travel function, since the participants did not explore the complete learning environment like in the first workshop.

In summary, and looking at the findings of the three subthemes, the results show that the perceived presence of the participants can be considered to be high. Many participants mentioned that they feel present in the learning environment (Table III). In addition, most participants also reported that they felt very engaged while working with the system, because the learning environment seems realistic.

E. Concept Mapping

To illuminate the overall learning success of participants, a total of ten concept maps from five learners (five original maps and their revisions for L1 to L5) as part of the *first workshop* as well as six concept maps from three learners (three original maps and their revisions for L2, L3, and L4) from the *third workshop* were constructed and subsequently analyzed.

First Workshop Results

Table IV summarizes the scores achieved before and after working with the 360-degree learning environment during the *first workshop* [60].

Comprehensiveness: Three learners (L1, L2, L5) show minimal coverage of the work process in their concept maps in both instances of knowledge elicitation. They did not profit from the learning phase that was meant to show a broader understanding of the subject matter. The concepts remain abstract with limited relevance for process execution. One of the remaining learners (L4) greatly improved, adding several key concepts necessary to properly interact with both the computer and the 3D Printer.

TABLE IV
CONCEPT MAP - ACHIEVED HOLISTIC SCORING (FIRST WORKSHOP)

Holistic Scoring		L1	L2	L3	L4	L5	Sum
Compre-hensiveness	Pre	1	1	2	1	1	6
	Post	1	1	2	3	1	8
Organization	Pre	1	2	1	1	1	6
	Post	1	2	1	2	1	7
Correctness	Pre	1	1	1	1	1	5
	Post	2	2	1	3	1	9
Aggregation	Pre	3	4	4	3	3	17
	Post	4	5	4	8	3	24

Organization: Regarding the maps' organization of knowledge, only one learner (L4) performed better after the intervention. From a primarily linear organization of concepts, the interconnectedness of the different hierarchies (branches) of work-process-oriented relevant knowledge was highlighted in the second knowledge elicitation phase. In the case of L5, the concept map shows even less interconnectedness, focusing on a linear documentation of the process steps.

Correctness: Three learners (L1, L2, L5) show increased mapping performance regarding the correctness attribute of concept maps. Previously naïve representations with inaccuracies and misconceptions about the work process are revised. In some cases, spelling and grammatical errors are addressed. Like with the two other attributes, L4's performance improved significantly, properly addressing supervision and finalization of the 3D printers' start-up.

Aggregated: The aggregated scores for each participant but L4 show little improvement in concept mapping performance. While the participants comply with the general rules of the method, documenting their knowledge in as much detail as possible is not done to such an extent that changes made to the maps could be attributed to a higher performance level.

Third Workshop Results

Table V summarizes the scores of the participants L2, L3, and L4 before and after the learning phase of the *third workshop.*

Comprehensiveness: Similar to the first workshop results, L2 shows little coverage of the work process, though additions made to the concept map after the learning phase are meaningful, thus leading to an increase in the comprehensiveness score. The same can be said for L3, where the learning phase leads to the addition of substantial concepts regarding software operation. L3 began with a concept map that was less comprehensive than during the first knowledge elicitation phase of the first workshop. L4's performance was better before the learning phase of the third workshop than before the learning phase of the first one. Yet, the participant made very few changes afterward, which is in stark contrast to the improvements during workshop one.

Organization: Both L2 and L3 slightly improved after the learning phase regarding their map's organizational features. Additions made to the concept maps are properly integrated into the existing map structure using features such as cross-links between concepts. L4 started with a primarily linear representation of the work process, contrasting her network-like structure of the very first knowledge elicitation phase.

TABLE V
CONCEPT MAP - ACHIEVED HOLISTIC SCORING (THIRD WORKSHOP)

Holistic Scoring		L2	L3	L4	Sum
Compre-hensiveness	Pre	1	1	1	3
	Post	2	2	2	6
Organization	Pre	2	1	1	4
	Post	2	2	1	5
Correctness	Pre	1	1	1	3
	Post	2	2	2	6
Aggregation	Pre	4	3	3	10
	Post	6	6	5	17

Correctness: All three learners improved regarding the correctness of their maps. Inaccuracies of the work process are mainly addressed by adding new concepts to the maps (see comprehensiveness). L3 could achieve a higher score after the learning phase of the third workshop than during the knowledge elicitation of the first workshop. L4 made very few changes to her concept map, even falling behind her performance after the learning phase of the first workshop.

Aggregated: For the aggregated scores, L2 was able to achieve a higher score than after the first workshop's learning phase. The same can be said for L3, except for his pre-learning phase score, which was lower than before and after the learning phase of the first workshop. L4's overall performance decreased compared to her first workshop results, showing less compliance with the elicitation method.

VII. DISCUSSION AND LIMITATION

Our design-oriented research approach illustrated that utilizing 360-degree learning environments can help employees accomplish new tasks in their work processes. The perceived motivation and engagement of the users during our workshops was high, although the results of the testing were qualitative. A similar observation has been noted by other authors who have used 360-degree learning environments to simulate realistic training [3, 61].

In addition, the results revealed that the motivation and engagement depend in part on the degree of novelty of the 360-degree technology for the users. Especially at the beginning of the workshop series, the participants experimented a lot with the application. This effect is seen in other studies, where new technologies are used in work processes [62]. In the process, they explored areas of the inter-company vocational training center that they were not yet familiar with. Afterward, they went to the 3D printer to accomplish their training task. This free exploration of the working place in the virtual world is a great advantage of the 360-degree environment, as work processes are not disturbed [63]. However, the implemented quick travel function has restricted this exploration because the users can now go to their workplace very quickly. This could explain the decrease in motivation and engagement compared to the first workshop. In addition, the enthusiasm for the technology decreased after getting accustomed to the system [28]. Although we were aware of this effect, we cannot make a clear statement as to whether this effect is amplified when the platform is used in the long term. Consequently, the implementation of the quick travel function is definitely worth discussing when utilizing immersive learning technologies over a longer period of time. While the function may decrease the exploratory learning possibility for beginners, it can help experts be more efficient in their learning process. This allows employees to concentrate fully on problem-solving when they are already familiar with simpler aspects or if new training components are integrated into an already existing training, e.g., if pieces of training are updated. Through the realistic 360-degree learning environment in combination with microlearnings, authentic simulations of problems are possible [39]. Furthermore, the combination of 360-degree learning and microlearning enables the situational involvement of the employees in the virtual learning environment [64]. Our results regarding the observation of the video indicate that the employees have few problems learning new working processes. This observation could be confirmed by the interviews. Following the guiding questions by Pedroli et al. [50], we surveyed the sense of presence among the learners by measuring the perceived spatial presence, the engagement, and the realism of the learners during the usage of the system. Our results show that the users feel present in the 360-degree learning environment. Because the users felt like they were part of the environment and also assessed it as realistic, we were able to show that the commitment of the users also improved. This commitment is a central building block for the design of effective learning material [35], as well as for the design of VR environments in general [9]. Furthermore, this is particularly evident in individuals who reported that they had little motivation at the beginning and then reported that they had fun. At the same time, through the implementation of integration elements, users were able to independently control their actions within the learning environment. This clear situational reference to one's own workplace as well as to the work task can reduce the cognitive load of the employees in the learning process [20]. Due to the realistic design of the 360-degree environment, the users had no problems finding their workplace.

The concept map results are ambiguous though interesting from a knowledge elicitation standpoint. While improving within workshops, thus showing short-term performance increases, the long-term acquisition of work-process knowledge was riddled with conceptual condensations (L2 and L3), creating less expressive concept maps that still may be enough for the participants to adequately reproduce the necessary procedures in the real world. The step-by-step documentation of work processes was of great help in the short term but might be a hurdle when used as a resource for a longer period of time, making more diverse representations of the work process a sensible consideration (L4).

Regarding the usability and the integrated elements and functions of the system, the majority of learners showed no motion sickness [4]; there were only minor technical problems that can be rated as not significant. Finally, the interactive 360-degree learning environment can be described as *effective* because the learners were able to achieve their task or goal [50]. All participants reported that they liked the interactive 360-degree environment very much and had no difficulties with the operation. Two learners reported that they felt nervous because they did not want to break anything on the machine. They reported that without the trainer in the background, they would probably not have dared to continue working independently. This could be an indicator that the integration of microlearning in the 360-degree learning environment can improve the understanding of the single microlearning elements but also have some limitations. Each microlearning element actually represents a small work process, which should be quick and easy to learn. However, the necessary connection between these microlearning elements is missing [65]. It was these connections between the individual microlearning elements within the learning environment that the two learners were unsure of how to proceed with. The numbering of microlearning elements to develop a coherent work process could be an easy solution to creating complex learning processes within 360-degree learning environments [9]. However, we are aware that this solution will be limited, especially in the case of very complex or longer work processes.

Overall, it can be stated that virtual 360-degree learning environments provide enrichment for the teaching and learning process, especially for inexperienced learners. As L4 stated during the evaluation: "I would rather use the 360-degree environment because the steps are clearly shown. A young child also knows how to use 1, 2, 3. The colors are also clear and familiar". The results show that the learners are *consistently engaged and motivated* to use the interactive 360-degree environment because it is a helpful support during work processes. Initially, some were afraid to do something wrong (L6), others were happy (L4), interested (L2), or had negative experiences with other systems (L1) and appreciated the smooth functionality as motivation (L7). All learners would recommend the interactive 360-degree learning environment to their colleagues. For example, L2 said, "If I had this learning environment for the exam [for a further training], it would have been much easier".

Although we provided a rigorous evaluation of our system, our research is not without limitations. First, the number of participants is small. This is caused by the production setting, where often only smaller teams can work on a specific task. To overcome this problem, we conducted a rigorous evaluation approach with three workshops and different evaluation methods to give insights into the development process of the system as well as the influence of the system on key learning outcomes. Second, regarding the variables of motivation and engagement, our results cannot be generalized and just refer to the developed learning environment. Third, we cannot say anything about the internal constitution of the group. Although we tried to put together a group that was as homogeneous as possible, we could already see in the discussions that some participants were much more enthusiastic about technology than others. Against this backdrop, the statements made in the second workshop had only limited value for us. Consequently, we decided to only use the data from the second workshop for the further development of our platform and not to measure other learning outcomes.

VIII. Conclusion

In this paper, we designed a user-centered 360-degree learning environment with integrated microlearning elements for work-process learning. For this purpose, we developed five central design elements for the design of 360-degree learning environments for work-process learning. Thereby we follow the concept of microlearning and situated learning theory to develop a learning environment that meets the requirements of the employees for work-process-integrated learning. To validate our rigorous and user-centered approach, we conducted three workshops to develop our application and to evaluate the learning outcomes of the users of the platform. Our results show that the learners were positive about the 360-degree interactive work-process-oriented environment. Thus, the simple and clear usability, as well as the easy and discreet user interface, were praised. The learners were also impressed by the simultaneous simplicity and detail of the microlearning.

Following the questions of Pedroli et al. [50], we show that the effectiveness, efficiency, and satisfaction of the 360-degree interactive environment was increased by the usage of the system. In terms of usability, the majority of learners showed no signs of weakness. There were only minor technical problems that can be rated as not significant. Finally, the interactive 360-degree learning environment can be described as effective because the learners were able to achieve their learning goals [3, 50].

As a practical contribution, we present five design elements for learning service providers in order to create interactive 360-degree learning environment that support the learning process by increasing learning outcomes. Furthermore, we offer an approach to combining microlearning with a virtual 360-degree learning environment to support the learning process of employees. Additionally, we provide a theory of design and action by offering design elements for the development of immersive, present 360-degree learning environments. Furthermore, we shed new light on the influence of interactive 360-degree environments and microlearning and show that these kinds of learning environments have positive effects on the learning success and motivation of learners.

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