The Importance of Separation in the Creation and Usage Phases of Augmented Reality Content Using Social Cognitive Theory

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Abstract

Although Augmented Reality-based Process Guidance Systems bring enormous potential savings to organizations, this technology is often not used beyond prototyping. One possible reason is that creating AR content requires advanced programming skills and deep spatial knowledge, which many SMEs lack. To address this challenge, AR authoring tools should enable novice users to create AR content. In this DSR project, we propose an AR authoring tool that novice users can apply as an innovative artifact to solve this problem. We elaborate on the third theoretical grounded design principle based on the social cognitive theory to understand the demands of creating and using AR content. We evaluated the developed software artifact in a field study with 12 participants. Our results show the different sources of self-efficacy in the creation and usage phase of AR content, highlighting the need for separation.

Keywords: Augmented Reality Authoring, Process Guidance System, Design Science Research, Social Cognitive Theory

1. Introduction

Through the use of Augmented Reality (AR) technology, the appropriate digital information will be displayed in the needed place on-site at the right time (Azuma, 1997). This newly emerged human-machine interface (Liu et al., 2017) has led to the appearance of new types of interactions and applications over time. As application areas continue to broaden, so too do the challenges. One of these challenges is the complexity of creating meaningful AR content (Arth & Schmalstieg, 2011). For instance, developing an AR application in an industrial context requires in-depth domain knowledge and advanced programming skills. Furthermore, creating and placing 3D elements in the physical environment requires deep spatial knowledge (Azuma, 2016). Consequently, technically skilled developers closely collaborate with domain experts to develop AR applications. As a result, 64 % of all AR applications in the engineering sector are individual developments (Palmarini et al., 2018). Individual developments are often not suitable for the use of AR outside of a prototypical evaluation. Even small changes in the process can mean an expensive and time-consuming adaptation of the application.

To counteract these challenges, scientists and practitioners look into so-called AR authoring tools (MacIntyre et al., 2005). These tools allow novice users to create AR content by accessing pre-built 3D models, animations, and annotations (Nebeling & Speicher, 2018). The term novice users in this work means users with no programming experience and no AR content creation experience. Nevertheless, these novice users are domain experts in their field, e.g., service technicians.

However, on closer examination, most available Authoring tools are generally intended for experienced and technically skilled software developers, as many functionalities require extensive programming and 3D modeling skills (Nebeling & Speicher, 2018). Enabling novice users to develop independent AR content remains a challenge. Therefore, we designed an AR authoring tool based on a no-code approach.

This study addresses the application domain of process guidance systems (PGS) (Morana et al., 2017) in an industrial context since many existing AR applications are used as PGS in this context (Klinker et al., 2018; Kortekamp et al., 2019). A PGS is comparable to a car navigation system, which provides the driver with spatial information as they drive from location A to location B (Morana et al., 2019). Through a PGS, users are guided through their work steps to complete them in a process-compliant manner (Dorn et al., 2010). The AR-based PGS is a new approach to guide users in performing physical processes (Laviola et al., 2022). Here, users are shown the necessary information at the right places and times. By applying these AR-based PGS, industrial companies can achieve enormous savings potential, for example, by reducing the preparation time and failure rate during the assembly of large aircraft systems (Serván et al., 2011). Thus, an AR authoring

URI: https://hdl.handle.net/10125/106445
978-0-9981331-7-1

tool that enables novice users to develop such AR-based PGS offers great potential.

Although there is already some work on AR Authoring Tools and the PGS, we still see a gap in the existing literature. Researchers have separately instantiated and evaluated AR authoring tools to create AR content and PGS to use AR content. To the best of our knowledge, no study yet combines and compares these aspects and provides a comprehensive overview of how AR authoring tools must be designed to engage novice users to develop AR-based PGS. More specifically, this research aims to understand the different sources of user engagement to create and use AR content in an industrial context to provide design knowledge for future AR authoring tools. To do so, we draw on social-cognitive theory (SCT), concerned with how environmental and cognitive factors influence human behavior in a given context (Bandura, 1986). We draw on the SCT since AR content creation is important in SCT, as users create content through their own efforts and actions, leading to higher self-efficacy (Bandura, 1997). Therefore, we want to answer the following research question: *What impact do the different sources of user engagement in creating and using AR content in an industrial context have on the design of AR authoring tools?*

The study follows the design science research methodology (Kuechler & Vaishnavi, 2008) to answer the research question. As a result, we contribute theoretically by proposing design knowledge for AR authoring tools for novice users. We also provide a practical contribution with our design principle to assist in implementing similar tools. Finally, we present the different sources of self-efficacy in the creation and usage phases of AR content, highlighting the need to separate these phases.

2. Conceptual Foundations

2.1 Augmented Reality and AR-Authoring

Due to intensive research, AR has made significant progress and has been continuously developed by various industries and researchers in recent years. The technology can be found in various applications (van Krevelen & Poelman, 2010). Despite these broad applications and technological progress, AR has some technical challenges and limitations (Arth & Schmalstieg, 2011). Ashtari et al. (2020) identified eight fundamental barriers that prevent AR creators from getting started. These range from prototyping an initial immersive experience to the difficulties of testing AR applications. Recent research has focused on developing AR authoring tools to reduce the technical barrier to development.

One of the first AR authoring approaches was the application DART in 2005, an extension of Macromedia Director that allows users to specify complex relationships between the physical and virtual worlds (MacIntyre et al., 2005). This first approach leads to various new tools in the industrial sector, such as ACAAR (Zhu et al., 2015), HoloWFM (Damarowsky & Kühnel, 2022), HoloFlows (Seiger et al., 2019) or ATOFIS (Lavric et al., 2022).

All these AR authoring tools were inspiration for the development of our tool. However, we have identified a shortcoming in the current tool landscape, as most tools focus on a single concept. For example, the ACAAR (Zhu et al., 2015) and ATOFIS (Lavric et al., 2022) tools focus on the authoring of AR applications. The authors of the ACAAR tool propose a system consisting of two software components. On the one hand, the *Offline Authoring module* is used to create the content, and on the other hand, the *Context-aware AR Services* module provides context-aware visualizations (Zhu et al., 2015). In contrast, the authors of the ATOFIS tool propose an in-situ authoring process in which users perform the authoring exclusively on an HMD (Lavric et al., 2022). The HoloWFM tool focuses on the AR content (i.e., what information the service technicians need to complete their task) (Damarowsky & Kühnel, 2022). The HoloFlows tool focuses on connecting the digital world and the physical environment. With the help of this tool, users can connect different IoT devices (Seiger et al., 2019). Through the inspiration of these tools, we have developed a practical tool that connects the shown concepts.

2.2 AR-based Process Guidance Systems

PGS are often used to support the user in executing digital processes to work in a process-compliant manner (Morana et al., 2017). However, many physical steps exist in the industrial context where the use of digital PGS is limited. For this reason, the researchers initiated and evaluated AR-based PGS (Hönemann et al., 2023; Kammerer et al., 2018). AR-based PGS enables users to display the information they need at the right time, anchored in the right place in their physical environment.

Due to the consistent implementation of cyber-physical systems in the industrial context, more and more process data is available to users, which enhances the need for AR-based PGSs. This increasing flood of digital data creates a fundamental disconnection from the physical world (Porter & Heppelmann, 2017). While the physical environment is three-dimensional, the digital content on which we base new decisions daily is trapped in a twodimensional space, such as monitors or pages. This gap between the physical and the virtual world hinders the ability to make the best possible decisions (Porter & Heppelmann, 2017). Using AR-based PGS, important information about the process can be displayed to the user at the right time and place in the user's physical environment.

Several examples of AR-based PGS applications are in the field of aircraft manufacturing. For example, the authors Chen et al. (2019) have instantiated an AR application that guides the service operator through the cable assembly process of large spacecraft components. The cable assembly process in this domain is very complex and requires very high accuracy. For this reason, the authors have instantiated and evaluated a new tracking method (Chen et al., 2019). Another software solution in this application domain is the project MOON (Serván et al., 2011) at Airbus. The tool supports the service operators in the wiring harness installation by displaying both the work to be performed and the basic critical operating parameters in the physical environment of the operators. As a result, the preparation time could be reduced by 90%.

2.3 Social Cognitive Load Theory

We draw on a social cognitive theory (SCT) (Bandura, 1986) as a kernel theory to conceptualize and represent our contributions to design knowledge and to develop our design principles. SCT postulates that the continuous reciprocal interaction between behavioral, cognitive, and environmental factors determines human behavior. Specifically, SCT is concerned with how environmental and cognitive factors influence human behavior in a given context (Bandura, 1986). Self-efficacy represents the core of the cognitive factors of SCT, which is a form of self-assessment that influences decisions about what behaviors to engage in and the amount of effort and persistence to exert when faced with obstacles. Individuals with high self-efficacy are more likely to exhibit certain behaviors than those with low self-efficacy. Bandura (1997) proposed that self-efficacy is mainly driven by four different sources: the enactive mastery experience, the vicarious experience, the verbal persuasion, and the physiological and affective states. The enactive mastery experience is the strongest source of self-efficacy and is driven by the repetitive successful completion of tasks (Bandura, 1997). Vicarious experiences are created when individuals observe someone with similar abilities performing a task. Verbal persuasion is the thought and reinforcement of a person's belief that they have the ability to complete the task. A person's emotional and physiological state induced by task performance is the final source of self-efficacy (Bandura, 1997).

Self-efficacy is crucial in virtual environments created by AR/VR interfaces, with implications for various domains. A large area of research is related to understanding knowledge sharing and knowledge acquisition in these virtual environments (Chiu et al., 2006; Kim et al., 2011). The findings also show that self-efficacy, directly and indirectly, influences knowledge sharing in virtual teams (Hsu et al., 2007). Self-efficacy also significantly impacts whether users want to participate in virtual environments. Individuals with high self-efficacy are more willing to explore and try new experiences within virtual environments, as they believe in their ability to learn and adapt to new tasks and challenges (Pellas, 2014). Furthermore, SCT plays a crucial role in AR authoring, as users create AR content through their own efforts and actions during the authoring, which leads to higher self-efficacy (Bandura, 1997).

3. Research Method

This study is part of a Design Science Research (DSR) project (Hevner et al., 2004) focusing on designing innovative artifacts. We propose an innovative solution to a real-world problem (Gregor & Hevner, 2013). It addresses, on the one hand, the lack of design knowledge regarding user engagement during novice users' creation of AR content. On the other hand, it addresses the lack of design knowledge regarding user engagement during the usage of AR content in an industrial context for novice users to carry out their work in a compliant manner.

In this way, we want to improve novice users' access to AR technology. We adapted Kuechler and Vaishnavi (2008) DSR approach and separated the overall DSR project into three successive design cycles. This research focuses on the qualitative evaluation results from the field study from the third design cycle, which are based on the first two design cycles. We balance rigor and relevance in our research by instantiating our AR authoring tool in an industrial equipment supplier (Hevner et al., 2004) through the DSR project and evaluating it.

3.1 Design Science Research Project

Although this research focuses solely on the third design cycle, the following section briefly describes the entire DSR project to provide additional information and highlight the overall research goal.

In the **first design cycle**, we examined how AR applications can be integrated into these application domains in two organizations. For this purpose, we conducted a focus group and a think-aloud study in each organization to identify the requirements for AR applications in the respective contexts. Despite the different application domains, the focus groups and the think-aloud studies revealed that users have problems carrying out and documenting their physical tasks in a process-compliant manner. We then used the results from the literature review, focus groups, and think-aloud studies to formulate two initial design principles. We instantiated these initial design principles into two different software prototypes. Followed by evaluating the software prototypes in a case study and a think-aloud study. In line with the literature, our results have shown that using AR-based PGS offers great company potential (Choi et al., 2022; Tang et al., 2003). In addition, we have found that a major problem in practice is not using AR applications but the complex, time-consuming, and cognitively challenging creation of AR content, which requires strong programming skills and deep spatial knowledge. (Ashtari et al., 2020).

We began the **second design cycle** with ten interviews with experts in AR content creation to further understand AR content creation. We also read more on SCT to broaden our theoretical design base. We adapted the two design principles based on the SCT since individuals are generally more willing to embrace new technologies due to high self-efficacy. We then instantiated the design principles in a software prototype. In an study, we examined how the richness of the AR authoring tool affects self-efficacy, belief in success, outcome expectations, and task performance. Since we were able to prove a significant difference in the belief in success but no significant difference in self-efficacy by modifying the tools' richness, we now aimed to seek possible explanations for this discrepancy in the third design cycle. One explanation would be the different sources of enactive mastery experience during the creation and use of AR content (Bandura, 1997).

In the **third design cycle**, we want to reiterate the findings from the second design cycle with adapted software artifacts in a real-world application context at different industrial organizations. By doing so, we respond to the request of Peffers et al. (2012) for more real-world evaluations of DSR artifacts. Based on the findings of the second design cycle, we adapted and added a design principle and then implemented them in our final software artifact. To compare the findings from the second design cycle with the results from this design cycle, we consider the effect of the AR authoring tool in the same application context with real users and the related real problems in an industrial environment. In the field study, we evaluate the validity of the third design principle instantiated in a software artifact.

4. Designing an AR Authoring Tool

4.1 Design Requirements and Design Principles

Our formulated design principles (DP) are based on the schema proposed by Gregor et al. (2020), which suggests how DP should be formulated in order to be usefully applied in a real-world context. The authors point out the need to involve actors in formulating the DP so that they provide prescriptive knowledge of “how to do something to achieve the goal” (Gregor et al., 2020, p. 1622). The structure of a DP consists of the aim, the implementer, the user, the context, the mechanism, and the rationale (Gregor et al., 2020).

The first four design requirements, which form the basis for the first and second design principles we propose, are part of the first two design cycles and are addressed in the publication *blinded for review (2023)*. To better understand the software artifact, Table 1 shows the four design requirements, the two design principles derived from the SCT, and the interviews from the second design cycle.

Table 1. Design requirements and principles from the initial two design cycles.

Design requirements	Design principles
DR1: Enable novice users to create user-generated AR content.	**DP1:** Design of an AR interface as an AR authoring tool empowering novice users to contribute to the industrial context with user-generated AR content.
DR2: Design of an AR Authoring tool to create AR content.	
DR3: Provide users with abstract 3D elements that can be anchored to the users' physical environment.	**DP2:** Provide the AR interface with a library of abstract 3D elements and allow novice users to add their media to create complete and perceived useful applications in the industrial context.
DR4: Provide novice users with the ability to create their media.	

The fifth design requirement aims to separate the AR creation and usage phases "Create user-generated AR content" and "Use AR content" from each other (**DR5**) since the personal experiences of success that influence the novice users' enactive mastery experience differ significantly in these phases. In the AR authoring phase, “Create user-generated AR content”, novice users experience success in the creation of AR content when they have created an application in which they believe that they have created an application that is useful for other parties

(Leung, 2009). In the AR authoring phase, "Use AR content", on the other hand, success is more likely to be defined by practical benefits such as reducing the error rate and saving time or costs. Therefore, it is only perceived as successful if the application offers visible economic or social added value for novice users (Porter & Heppelmann, 2017; Serván et al., 2011; Tang et al., 2003). In addition to the enactive mastery experience, verbal persuasion fundamentally differs in these AR authoring phases. Verbal persuasion in the AR authoring phase, "Create user-generated AR content," is mainly driven by the user's conviction that they can accomplish the task. Users in virtual teams who are not convinced of their abilities to share knowledge do not perform certain behaviors (Bandura, 1986). In this context, creating AR content to guide users through their work in a process-compliant manner represents knowledge sharing (Chiu et al., 2006; Hsu et al., 2007). In the AR authoring phase, "Use AR content", on the other hand, the verbal persuasion is influenced by two factors: the novice users' belief that they have the technical skills to perform the task (i.e., to repair the technical asset) and the quality of the instructions available to them which increases their belief in success (Laviola et al., 2022).

The design requirement aims to consider the differently driven enactive mastery experience and verbal persuasion in creating and using AR content in the industrial context. The design requirement thus forms the final design principle that we propose: ***DP3:*** *The AR interface should provide novice users with a clear separation between creating user-generated AR content and using AR content.*

By initiating the prototypes based on all these approaches, we intend to evaluate these approaches and then adapt the design principles accordingly. Table 2 provides an overview of the fifth design requirement that formed the basis for our proposed third design principle.

Table 2. Design requirement and design principle.

Design requirements	Design principles
DR5: The novice user's success and belief in their own abilities differ significantly when creating AR content than when using it.	**DP3:** The AR interface should provide novice users with a clear separation between creating user-generated AR content and using AR content.

4.2 Instantiation of the Design

The AR authoring tool is a standalone tablet tool that doesn't require additional software or hardware. This applies to both the creation and use of AR content. The tool adopts a no-code development approach, providing a library of abstract 3D elements and the ability to create custom media. The following chapter provides a detailed overview of the fundamental architecture of the AR authoring tool, which consists of three main software components.

The first software component is the 2D Node Editor. This software component determines the structure and sequence of the AR-based PGS. It represents the initial basis for each instruction to be created. The structure can be defined through three different node types. The first node type is the Info-Node, where only 2D elements can be added to the application. Both 2D and 3D elements can be added to the application in an Instruction-Node. In the case of an Exploration-Node, only location-dependent 3D elements can be added. The left side of Figure 1 gives an overview of the 2D Node Editor, in which a simple AR-based PGS is created.

The contents of the different node types are part of the second software component, the 3D Authoring Environment. This content enriches the previously defined process flows with the necessary content to generate comprehensive AR instructions. Three elements, the 3D elements, the media, and the nodes, form the foundation of the 3D authoring environment. The first element provides the user with a total of seven abstract 3D elements, ranging from a simple arrow, which can indicate a position in the physical environment, to an omnidirectional attention funnel, which acts as a navigation through the users' physical environment (Biocca et al., 2007). The 3D elements can be dragged and dropped to the desired positions, and users always have the opportunity to adjust the position. Adding different media is also part of the second element of the software component. The third element of the software component is the different node types, which all differ in their content. The right side of Figure 1 shows the 3D authoring environment of an Instruction-Node.

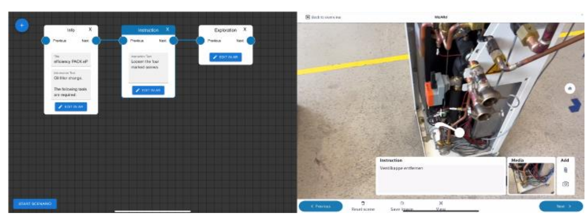

Figure 1. Software Artifact.

The content from the 3D authoring environment is passed to a scenario, which can be accessed or created using the scenario manager. The third software component, the Viewer Mode, displays the created scenarios as created without the ability to modify the AR content. The 2D and 3D content is rendered precisely where the creators placed it.

5. Evaluation of the Design

To evaluate our DP3 and the utility of our software artifact, we conducted a summative and naturalistic field study with service technicians with different backgrounds (energy technology, measurement systems). We follow the evaluation methods proposed by (Hevner et al., 2004). The observational approach, exemplified by case studies or field studies, is well suited for our application domain. In the previous design cycle, we used a controlled laboratory experiment to demonstrate the impact of our proposed two design principles and the software artifact and to demonstrate their application using a quantitative approach. In this third design cycle, we report the results of the interviews with the participants after using the AR authoring tool. The field study enables us to evaluate the impact and validity of DP3 and the utility of the AR authoring tool in an industrial context, which we could not test in the controlled laboratory experiment.

We decided to use interviews as they allow for collecting rich empirical details regarding the different obstacles, impressions, and utilities perceived by the users when creating and using the AR content. In addition, interviews are a means of collecting extensive data and, in our case, can be used to evaluate the potential utility of our AR authoring tool by gathering experts' opinions from practice after using our software artifact.

5.1 Setup and Procedure of the Evaluation

We designed the field study with six main elements. The first step in the field study is a short demonstration of the AR authoring tool, so the participants know its features and how to use it. A hands-on exercise follows this, so the participants know how to use the tool in practice.

The third step is the main element of the field study. The participants were asked to map a part of the assembly instructions of their technical assets with the AR authoring tool. For this purpose, an assembly step was chosen that is carried out at regular intervals (e.g., as part of semi-annual maintenance) and thus represents a representative task. The task is completed when the instructions have been mapped completely in AR or when the time (20 min) runs out. Since we had to keep to a schedule, we also limited the time to 20 min to ensure that all participants could participate in the study at the selected times. As described in the chapter "Instantiation of the Design", another important aspect of the tool is using AR content.

The use of the content represents the fourth step in the field study. For this purpose, one of the authors of this study created detailed instructions in advance, representing the same assembly step from step three of the field study. The participants then used this instruction to execute the maintenance step.

The fifth step of the is the empirical data collection. After using the AR authoring tool, a semi-structured interview was conducted with the participants to get their opinions about the tool.

Finally, we handed out a questionnaire for the participants to fill out. In this questionnaire, we asked for demographic data and, for self-efficacy, perceived usefulness, and perceived functionality.

5.3 Sample and Interview Process

The interviews were structured using a basic interview guide, where the interviewer ensured that all questions from the interview guide were covered during the interview. In addition, related discussion topics were allowed to increase the richness of the information collected (Myers & Newman, 2007).

The field study was conducted with employees from two different companies in Germany with different backgrounds. Rather than using a large sample of novice users, we were interested in understanding how service professionals would use AR authoring tools. We therefore purposefully sampled two industries that differed in their degree of technology requirements and identified 12 participants across two companies for the field study. Five of the 12 participants were women, and seven participants were men. The average age of the participants was 36.73 (SD=7.54) years.

During the semi-structured interview, we asked participants to share their first impressions of using the tool, including its strengths and weaknesses. Next, we asked participants to describe the functionalities and information elements that were important to them during the creation and use of the AR content. Finally, we asked participants about the practicality of the tool and the AR content created, and its advantages over existing systems (i.e., service manuals). The interviews were recorded and transcribed afterward.

We relied on abductive reasoning to analyze the rich data we obtained during the field study (Sarker S. et al., 2013). The experts' opinions on using and creating AR content with our software artifact were coded using open coding through short descriptive statements that summarize the core idea of the text passage (Wiesche et al., 2017). The subsequent analysis of the codes revealed several first-order concepts. More abstract second-order themes emerged by evaluating the similarities and differences between the first-order concepts. Table 3 shows an example of this analysis process with exemplary quotes from the transcripts.

Table 3. Illustration of the coding process.

Illustrative quotes from the data	First order themes	Corresponding dimensions of SCT
"W*e also have the older generation, who don't like to have their cell phones attached to anything, so it should be possible to export the instructions in text form*." (#10)	Creating AR content success is based on other parties' use	Different sources of enactive mastery experience
"*This saves time in any case, as it can show more than a service manual*." (#5)	AR content success is based on economic/social advantages	
"*The process of learning how to use these instructions as well as how to create them in such a short time, like in five minutes, was very impressive*." (#3)	Belief in the ability to create AR content	Different abilities of verbal persuasion
"*The video and also the arrows so that you could see exactly where you have to go, what you have to do. That was particularly helpful because then you can actually do it yourself, which is also the goal and purpose of the thing*." (#7)	Belief in the quality of the instructions to work in a process-compliant manner	

6. Results of the Field Study

The field study results show how the AR authoring phases "Create user-generated AR content" and "Use AR content" differ in both enactive mastery experience and verbal persuasion. The field study results show how the phases of creation and use of AR content differ for both the enactive mastery experience and verbal persuasion. While the enactive mastery experience during the creation phase is mainly driven by the belief in the usefulness of the content through other parties (can or would the service technician use these AR-based PGS), the enactive mastery experience during the usage phase is predominantly characterized by the expected economic/social advantages (does the AR-based PGS bring a benefit for my organization or for me). The verbal persuasion during the creation phase is mainly driven by the user's belief in their ability to create AR content (do I know the AR authoring tool well enough to create an AR-based PGS). On the other hand, verbal persuasion during the use of AR content is primarily driven by the quality and richness of the AR-based PGS.

6.1 Sources of Enactive Mastery Experience

In the AR authoring phase, "Create user-generated AR content" the enactive mastery experience is primarily based on the success of other parties' use of the AR content. No participants had expressed difficulties regarding creating AR content with a handheld device. However, 8 out of 12 participants did not perceive creating AR content alone as a success. Instead, they noted in the interviews that the next step should be to provide the created AR content in different forms and on different hardware, as their colleagues have differing needs. For example, some of their older experts want to continue working with paper documents, while others prefer a smartphone or HMD so that they can work hands-free. Thus the perceived success of the AR content created was based on the broad range of possibilities for using the AR content created, which requires a clearer and more versatile separation of the creation and use of the AR content. One expert explained: "It would be good if the instruction that one has just created with the tool could be exported in some way so that one then receives the instruction, for example, in text form or some other form. So that a technician for their colleagues in the field, the instructions can record here with AR, and that can then be exported into a document." (#10)

We found out that in the AR authoring phase, "Use AR content" the source of the enactive mastery experience is mainly based on the economic and social benefits. While only three participants mentioned an economic/social benefit from the quick and easy creation of AR content, 9 out of 12 participants highlighted the economic/social benefits of using AR content. One of the biggest advantages that the participants mentioned regarding using AR content are various benefits of the AR content for training and teaching new colleagues. Compared to a video, users can be trained at their own pace and on the physical machine without needing their own trainer. Another advantage that has been mentioned more often is the time and error reduction of this AR content, as by using the AR content, the user is guided step by step through a maintenance/repair process. *"[...] the advantage compared to a recorded video is that you can follow the individual steps independently on the end devices by clicking through these steps based on* *your individual pace. You're not reliant on the video, but do it as quickly and as slowly as you like […]"* (#1)

Greater versatility of use also plays a crucial role in the actual use of AR content. The social and economic benefits were often linked to the need to expand use across a wider range of hardware. For example, some participants said that they saw an advantage, whether in training or process support if the AR content created could be used on a smartphone or HMD. "*It's better suited for training purposes. You have step-by-step gradations, so with the video, you're kind of sucked through, and you have to pause if you want to know something again, and here it's just nice and slow. The important thing is, and this is always the case with augmented reality, that you have to look at how you get the information and still have your hands free to continue working […]*" (#10)

6.2 Sources of Verbal Persuasion.

In the AR authoring phase, "Create user-generated AR content," the verbal persuasion is primarily driven by the participants' belief in their own abilities to create AR content on their own using the AR authoring tool. When asked about their concerns about the process of creating AR content, none of the participants expressed major difficulties in creating AR content. On the contrary, 8 of the 12 participants were positive about creating AR content. The participants noted that despite the short introduction and presentation of the tool, it was impressive that they could independently create AR content. However, participants also noted that they could not use the AR authoring tool in some places without this short introduction at the beginning of the field study. For example, the interaction with the 3D elements on the tablet is not intuitive since, in order to move the 3D elements, the tablet has to be moved. "Despite the fact that I get from you no or only a small instruction to the tool, I could work intuitively with it. A short tutorial like a one-pager, or a short demo video is enough to work with the tool quickly." (#6)

For the AR authoring phase, "Create user-generated AR content" only two participants suggested an improvement so that the tool would further support them in their belief in their own abilities to create AR content. Both commented that many PGS are similar in structure and differ in only a few steps. For this reason, it would be useful if the content could be duplicated. In this way, the time required for the creation process could be reduced.

In contrast, the source of verbal persuasion in the AR authoring phase, "Use AR content" is the participants' belief in the quality and usefulness of the AR content. Here, all participants expressed a need for improvement to exploit the full potential of AR content in their context of use. Suggestions for improvement are analogous to participants' expressed concerns about the source of the enactive mastery experience to the need for more versatile uses of AR content. For example, there are the experts who do not need to be guided step-by-step through a process but only need to look up a step, or the users are unable to operate an iPad due to occupational safety devices, which require the use of an HMD. "*Yes, as I said, there would be for me once the handling of tablet and simultaneous work. So where do I place the tablet and now also with the background that I have oil on my hands, now I need the tablet again […]*" (#1)

7. Discussion

In this research, we examine how novice users can create AR-based PGS so that different novice users can use them to conduct physical tasks in a process-compliant manner. We present an AR authoring tool's system architecture consisting of three software components (a 2D node editor, a 3D authoring environment, and a viewer mode) as well as the third theoretically grounded design principle provides prescriptive knowledge about the differences novice users need when creating and using AR content in an industrial environment, highlighting the need to separate these two AR authoring phases.

Following Gregor and Hevner (2013) DSR contribution framework, we consider our contribution as an improvement as we successfully provide a new solution (AR Authoring Tool to create AR-based PGS) to an existing problem (Complexity in AR content creation prevents SMEs from experimenting or using the technology). Similar to software development (Maruping & Matook, 2020), where no-code or low-code tools help novice users develop new applications, AR authoring tools help novice users create AR content in their application domain. We have proved the different sources of enactive mastery experience during the creation and use of AR content (Bandura, 1997). Thus, we can consider the third DP we proposed as confirmed. For the development of future AR authoring tools in this context, the third DP should be taken into account by separating the creation and use of the content within the tool. Compared to commercial tools such as Microsoft Dynamics 365 Guides (Lavric et al., 2022), where the creation and use of the content are also separated, our design principle, however, suggests that the separation should take place on the AR interface so that the novice users can, for example, also create instruction manuals at the customer site.

In addition, the AR Authoring Tool also provides a practical contribution. The tool represents a valuable tool for SMEs to identify which processes can be meaningfully visualized in AR. The library of abstract 3D elements, the ability to create custom media, and familiar hardware allow novice users from SMEs to represent their processes in AR. These processes can then be used and evaluated by other novice users to carry out their work in a compliant manner.

Although we conducted the DSR project and the evaluation described in this paper according to the established guidelines, potential limitations still require further research. First, the evaluation described addresses only two small processes in an industrial context. In the evaluation, all work instructions could be mapped in augmented reality. Still, we cannot deduce from these two process steps that all work instructions in a manufacturing application domain can be mapped with these AR elements. Therefore, mapping multiple processes in further evaluation may lead to different results. For example, other evaluations in the manufacturing domain could investigate whether media and 3D elements are sufficient to display all work instructions in AR. The second limitation of our study is that the evaluation was conducted with only 12 participants from a representative target group, limiting our findings' generalizability. An evaluation with additional participants may lead to different findings. Therefore, a study with additional participants could be conducted to test our design principles' generalizability further.

8. Acknowledgments

This research was sponsored by the German Federal Ministry for Education and Research in the project WizARd under the reference 02K18D180. Further information can be found at: https://wizard.tu-dortmund.de/.

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