Process Management in Virtual Worlds – Virtual Reality as Innovation Driver in Organizations

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Ludger Pöhler, M.Sc.

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Dekan
Prof. Dr. Frank Teuteberg

Referenten
Prof. Dr. Frank Teuteberg
Prof. Dr. Oliver Thomas

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Preface

This cumulative dissertation was completed during my three and a half years as a research assistant at the Department of Accounting and Information Systems at the University of Osnabrück. The PhD journey was characterized by many exciting experiences and impressions that helped me to mature professionally and privately. During this intensive and busy phase, I experienced significant encouragement and support. Subsequently, I would like to thank those who helped me with their words and deeds during my promotion.

First, I would like to thank my supervisor Prof. Dr. Frank Teuteberg for the excellent mentoring during the last three-and-a-half years. He gave me the opportunity to explore an exciting and innovative research field and provided me with a comfortable working atmosphere as well as valuable feedback on the individual research contributions. Next, I would like to thank Prof. Dr. Oliver Thomas, who consented to serve as this dissertation's co-lecturer.

Furthermore, I would like to thank all the project members from the SoDigital research project. Due to the numerous meetings, workshops, and personal conversations with the scientific and practical partners, many inspiring ideas emerged that I could beneficially integrate into this dissertation.

I would also like to thank my colleagues from the Department of Accounting and Information Systems at the University of Osnabrück. Special thanks are extended to my long-time office colleague Dr. Julian Schuir, who always supported me during my PhD journey regarding expertise, methodology, and motivation. In addition, Mr. Kevin Kus, Mr. Tim Arlinghaus, Mrs. Patricia Kajüter, Dr. Eduard Anton, Dr. Thuy Duong Oesterreich, and Mrs. Fabia Hettler have always contributed to a pleasant and productive working atmosphere throughout the years. I would also like to thank Mrs. Marita Imhorst and Mrs. Barbara Meierkord for their constant and kind support regarding organizational challenges.

Moreover, I would like to thank my family and friends, who encouraged me to pursue a doctorate and supported and believed in me for all these years. A special thanks is extended to my parents, Hildegard and Ludwig, and my siblings, Carolin, Alexander, and Katrin, who have always been a personal support. Particularly, I would also like to thank my girlfriend Gunda, who always had a sympathetic ear and supported me warmly.

Osnabrück, October 2023 Ludger Pöhler

Notes on the Structure of the Document

The dissertation is divided into two parts: Part A represents a stand-alone contribution based on the individual contributions from Part B. Seen as a whole, Part A synthesizes the results of the eight individual contributions. These contributions are presented in Part B. All of these contributions were published in international conference proceedings or journals. Although they build on each other thematically, they can each be regarded as stand-alone contributions with their own specific focus. Therefore, the articles also have their respective original citation and formatting style.

Contents

Part A: Introductory Overview

List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AR	Augmented Reality
BPM	Business Process Management
BPMN	Business Process Model and Notation
CAD	Computer-aided design
CBA	Cost-benefit analysis
DSR	Design science research
ECIS	European Conference on Information Systems
FEDS	Framework for Evaluation in Design Science
HCI	Human-computer interaction
HMD	HMD Praxis der Wirtschaftsinformatik
ICIS	International Conference on Information Systems
ID	Identifier
IS	Information Systems
IT	Information Technology
LiDAR	Light Detection and Ranging
MWU	Mann-Whitney-U test
RQ	Research Question
SME	Small to medium-sized enterprise
TOEI	Technology, Organization, Environment, Individual
TTF	Task-Technology Fit
UI	User Interface
VHB	Verband der Hochschullehrer der Betriebswirtschaft e.V.
VR	Virtual Reality
WKWI	Wissenschaftliche Kommission Wirtschaftsinformatik
XR	Extended Reality

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1 Introduction

1.1 Motivation

Due to intense competition, growing price pressure, and an increasing need for digitalization, organizations must transform their business processes (Kerpedzhiev et al. 2021). Redesigning business processes can help organizations increase external competitiveness and simultaneously provide potential to design workflows that improve employee satisfaction and health (Baethge et al. 2015; van der Aalst 2013). Operational business process management (BPM) aims to ensure structural and organizationally embedded execution by eliciting and modeling processes and subsequently analyzing, redesigning, and implementing them (Becker et al. 2000; Dumas et al. 2013). Only through jointly understanding processes organizations can achieve continuous improvement, as a quote often attributed to Deming (Allen et al. 2010) describes:

"If you can't describe what you are doing as a process, you don't know what you're doing."
William Edwards Deming, Pioneer of quality management

The importance of BPM is steadily increasing. In a 2021 survey among 336 managers, 83% stated that BPM plays an important role in their organizations (BearingPoint 2021).[1] Those who considered BPM very important nearly doubled compared to 2012 (from 19% in 2012 to 35% in 2021). However, organizations face manifold operational challenges in executing BPM activities, meaning that potential for improvement remains unrealized and the high level of importance of BPM cannot be met (BearingPoint 2021).

The model-reality divide is the first big challenge, which describes the state that the reality and the derived or descriptive model do not match (Bögel et al. 2014; Schmidt and Nurcan 2009). The main reasons for this divide are the model-consistency problem and the automated-fiction problem (Erol et al. 2010; Straatmann et al. 2022). The model-consistency problem is based on information pass-on barriers. Abstract graphical specification languages with high diversity, such as Business Process Modeling and Notation (BPMN, Recker 2010), impede non-experts' participation in modeling and active process design. The lack of contextualization makes it difficult to transfer mental models into formal process models (Nolte et al. 2016). Consequently, not all contributors can participate equally, leading to information pass-on barriers from losing valuable tacit-process knowledge. Moreover, the automated-fiction problem inevitably arises from the low level of employee integration in operational modeling and planning. Because important tacit

[1] The study questioned employees from medium and upper management in companies in Germany, Austria and Switzerland from different sectors such as mechanical engineering, public administration and the chemical industry.

knowledge is not integrated, target processes and models are developed based on unrealistic specifications and environmental conditions (Schmidt and Nurcan 2009; Straatmann et al. 2022). This poor integration can lead to lower employee acceptance and quality losses in the subsequent execution of the processes (Smith 2001).

Lost innovation is the second big challenge that BPM activities must face (Straatmann et al. 2022). On the one hand, low innovation is based on the motivation problem of employees and, on the other hand, on general project-management problems (Schmidt and Nurcan 2009; Erol et al. 2010). Workshops, interviews, or document analyses extract and document process knowledge (Fleischmann et al. 2012). These standardized formats, which are not overly creativity-enhancing, make it difficult for employees to enter into BPM and increase their motivation to participate (Straatmann et al. 2022). However, incorporating built-up experience and new employee ideas are key innovation drivers in organizations (Gibson and Birkinshaw 2004). Another challenge in BPM activities is the project-management problem. Different disciplines (e.g. construction, sales, assembly) must be unified due to diverging or conflicting objectives and prior knowledge (Erol et al. 2010). In particular, discipline-specific modeling conventions can lead to non-specialist disciplines being excluded from planning projects, making multi-perspective and participatory planning, development, and implementation more difficult (Herrmann 2012; Straatmann et al. 2022).

In addition to these general BPM problems, differences exist in the strategic embedding of BPM between organizations. In larger organizations, an independent business unit is usually responsible for managing and operating BPM activities. However, in small to medium-sized enterprises (SMEs), transforming business processes is usually carried out in parallel by the executive board or senior management alongside day-to-day business because of limited financial and human resources (Liao and Barnes 2015). The knowledge of these responsible SME employees about BPM tools is usually limited since they are typically not BPM experts. This means that specific and variant-rich tools represent an entry hurdle, especially for SMEs with little BPM experience to achieve transformation through BPM (Dallas and Wynn 2014).

1.2 Research Objectives

New BPM concepts and associated tools are required to meet the aforementioned challenges and enable organizations to innovate through BPM activities. These tools should be designed in a way that they enhance contextualization, increase motivation to use them, and enable barrier-free participatory process design.

Social software has already demonstrated added value in participatory business-process design (cf. Erol et al. 2010; Triaa et al. 2017). New concepts combine software-supported collaborative work with innovative and hedonistic technologies, where virtual reality (VR) particularly presents great potential for creative and collaborative idea development (Fromm et al. 2020). VR can be generally defined as the use of "immersive technologies to simulate interactive virtual environments or virtual worlds with which users become subjectively involved and in which they feel physically present" (Wohlgenannt et al. 2020, p. 457). Notably, the development of stereoscopic head-mounted displays by large technology companies such as Meta, HTC, and HP has caused increased consumer and industrial use (Rauschnabel et al. 2022). For example, in information systems (IS) research, Vogel et al. (2021) have already determined that multi-user VR is suitable for interactive, creative, and collaborative idea generation in design-thinking workshops. Furthermore, given the need for more contextualization in BPM activities (vom Brocke et al. 2021), including immersive three-dimensional (3D) VR environments provides an opportunity to link planned activities to their place of execution, thus, increasing contextualization. VR has also shown advantages in related application areas, such as training simulation or interactive knowledge transfer by providing multidimensionality and user activation (cf. Lacko 2020; Leyer et al. 2021), which also has the potential for solving BPM activity barriers. Moreover, immersive technologies in industrial use can exhibit long-term economic benefits, such as savings in quality, personnel, and mobility costs (Oesterreich and Teuteberg 2018). Additionally, since forecasts assume strong growth in the importance of immersive technologies in the workplace (PricewaterhouseCoopers 2021), it is reasonable to strategically investigate BPM research regarding the extent that potential from related research fields can transfer to process activities.

The core competence of the design-oriented IS discipline is solving real-world problems by conceptualizing and designing information technology (IT) artifacts that comprise a high degree of innovation and potential for effective implementation and use (Österle et al. 2011; Sonnenberg and vom Brocke 2012). In particular, the design science research (DSR) approach has proven suitable for generating new prescriptive knowledge about designing IS artifacts, such as methods, models, constructs, and instantiations based on existing knowledge (Hevner 2007). Thus, DSR's application provides promising potential for designing a VR artifact that can contribute to the solution of the motivating BPM challenges by drawing on existing knowledge. Since little prescriptive design knowledge exists for creating highly immersive IS (Wohlgenannt et al. 2020), this research gap can be bridged by developing, instantiating, and evaluating sound and rigorous design knowledge for VR in the work context. Additionally, the economic effects of implementing and utilizing generated artifacts constitute great importance in the practice-oriented research discipline IS (Oesterreich and Teuteberg 2018). Therefore, this dissertation aims to expand the limited knowledge base regarding the long-term economic evaluation of IS artifacts by developing a method for suitability- and utilization-based cost-benefit analysis (CBA) of IS and applying it to the generated VR artifact. Additionally, practical relevance and implementation must be ensured in the artifacts' development to ensure the successful dissemination of sociotechnical systems in organizations (vom Brocke et al. 2020). In the case of disruptive technologies such as VR (Psotka 2013), there is a particular lack of instruments and methods that support innovation management during implementation from a holistic, technical, organizational, environmental, and individual perspective (Hodgson et al. 2019). Therefore, this dissertation additionally aims to develop a tool to embed VR artifacts into organizations successfully. In summary, the following research questions (RQs) arise:

RQ1: What are the potentials of VR to overcome current challenges in BPM activities?

RQ2: How should a VR system for collaborative and contextualized process management be designed to overcome current BPM challenges and ensure added value for organizations?

RQ3: What are the specifics of the organizational implementation of VR and how can they be addressed?

1.3 Structure

This dissertation is divided into five sections to answer the RQs. After introducing the topic and the RQs' presentation, Section 2 addresses the classification of the individual research contributions. An overview of the publication outlet and ranking, a positioning in the form of an explanatory framework model to unify the individual contributions within the IS discipline, and an overview of the applied research methods are presented. Section 3 contains the key findings from the individual contributions and relates them to an overall context, addressing RQ1–RQ3. Section 4 discusses the findings by addressing research and practice implications and the limitations and future research. The dissertation ends with a conclusion in Section 5.

2 Research Design

2.1 Selection of the Research Contributions

This cumulative dissertation is based on the findings of eight individual contributions (A–H, Table 1). Each contribution underwent a multi-stage double-blind peer review process, with at least two experienced reviewers examining their quality regarding rigor and relevance.

The author contributed six papers as first author, one as second author, and one as the fourth author. Four papers were presented at international conferences and published in the respective conference proceedings. Two central individual contributions (B and E) were published at the most prestigious IS conferences, ECIS and ICIS, with publication B being awarded the best paper award of the track "Business Process Management in the Digital Age" and nominated for the best paper award of ECIS 2021 (Claudio Ciborra Award). Moreover, four journal publications are listed, with two publications in HMD, in particular, contributing to important dissemination in practice.

The VHB-JOURQUAL 3 from the Verband der Hochschullehrer der Betriebswirtschaft e. V. (VHB 2015) and the Orientierungsliste der Wissenschaftlichen Kommission Wirtschaftsinformatik (WKWI, Heinzl et al. 2008) serve as rankings to classify the publication outlets' quality. Additionally, some journals provide the Journal Impact Factor (JIF), indicating articles' citation frequency of the journal. Since paper A was published in a journal of organizational psychology, it is not listed in the above rankings. As the JIF of 1.802 is higher than one-third of the JIF of the C-ranked VHB (2015) journals, a C-journal classification according to VHB ranking is a reasonable comparison level.

Supplementary to the contributions listed in Table 1, this dissertation's author published two contributions at the most prestigious German IS conference Wirtschaftsinformatik (Ranking: A (WKWI), C (VHB)) and co-authored a book chapter (see Appendix 1). The findings from these contributions have been partially incorporated into the individual contributions of Table 1. Nevertheless, due to their differing focus, these individual contributions were not separately included in the cumulative dissertation.

ID	Bibliographic information[1]	Outlet	Ranking	
			WKWI	VHB
A	Straatmann, T., Schumacher, J., Koßmann, C., **Pöhler, L**, Teuteberg, F., Müller, K. and Hamborg, K.-C (2022). "Advantages of Virtual Reality for the Participative Design of Work Processes: An Integrative Perspective," WORK - A Journal of Prevention, Assessment and Rehabilitation, pp. 1765 –1788.[2]	WORK (Journal) JIF: 1.802	-	-
B*	**Pöhler, L.** and Teuteberg, F. (2021). "Closing Spatial and Motivational Gaps: Virtual Reality in Business Process Improvement," in Twenty-Ninth European Conference on Information Systems (ECIS 2021), A Virtual AIS Conference.	ECIS (Conference)	A	B
C	Schuir, J., **Pöhler, L.** and Teuteberg, F. (2022). "Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality-Marktes am Beispiel Oculus," HMD Praxis der Wirtschaftsinformatik (59:1), pp. 261–279.[3]	HMD (Journal)	B	D
D	**Pöhler, L.**, Schuir, J., Lübbers, S., and Teuteberg, F. (2020). "Enabling Collaborative Business Process Elicitation in Virtual Environments," in Lecture Notes in Business Information Processing (Vol. 391), B. Shishkov (ed.), Springer, Cham, pp. 375–385.[4]	BMSD (Conference)	-	C
E	**Pöhler, L.**, Schuir, J., Meier, P. and Teuteberg, F. (2021). "Let's Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling, " in Forty-Second International Conference on Information Systems (ICIS 2021), Austin, USA.[5]	ICIS (Conference)	A	A
F	**Pöhler, L.** and Teuteberg, F. (2022). "Unfolding Benefits of Virtual Reality for Workplace and Process Design based on Utility Effect Chains," in Proceedings of the Twenty-Sixth Pacific Asia Conference on Information Systems (PACIS 2021), A Virtual AIS Conference.	PACIS (Conference)	B	C
G	**Pöhler, L.** and Teuteberg, F. (2023). "Suitability and Utilization-based Cost-Benefit Analysis: A Techno-Economic Feasibility Study of Virtual Reality for Workplace and Process Design," Information Systems and e-Business Management (ISeB), pp. 1–41.	ISeB (Journal) JIF: 3.6	B	C
H	**Pöhler, L.**, Belda, F., and Teuteberg, F. (2023). "Das Extended-Reality-Canvas – Wie können Unternehmen XR-Projekte erfolgreich implementieren?," HMD Praxis der Wirtschaftsinformatik, pp. 1–20.[6]	HMD (Journal)	B	D

[1] Prof. Dr. Frank Teuteberg critically reflected on the structure, methodological design and content of all contributions and provided constructive feedback for improvement.

[2] Dr. Tammo Straatmann, Mr. Jan Schumacher and Mrs. Cosima Koßmann contributed equally to the writing of the article. They were responsible for the idea of the article, carried out the integrative review, and authored discussion and conclusion. The author of this dissertation contributed significantly to the conceptualization, leaded in the introduction and assisted in the analysis. Prof. Dr. Kai-Christoph Hamborg and Prof. Dr. Karsten Müller critically reflected on the methodological orientation.

[3] Dr. Julian Schuir was in charge of generating the article idea, the methodological conceptualization, the quantitative evaluation and the elaboration of the recommendations for action. The author of this dissertation contributed significantly to the introduction and related work. In addition, he assisted in the conceptualization, analysis of the data and the preparation of recommendations for action.

[4] The author of this dissertation was responsible for developing the idea of the article and the methodological approach. In addition, he was responsible for authoring the introduction, related work, data analysis, and discussion. Dr. Julian Schuir supported the conceptual design of the paper and the derivation of design principles and provided critical feedback. Mr. Simon Lübbers supported the execution and evaluation of experiments and expert interviews.

[5] The author of this dissertation was in the lead in writing the article and developed the methodological design. Additionally, he contributed significantly to the design knowledge, conceived and operationalized the evaluation cycles, and was responsible for discussion and conclusion. Dr. Julian Schuir provided significant support in the evaluation and the development of design principles. Dr. Pascal Meier provided critical feedback and assisted in visualizing the technical solution.

[6] The author of this dissertation was responsible for the development of the initial paper idea, its methodical design and the generation of action recommendations. Mr. Fabian Belda contributed significantly to the conceptualization and design of the artifact and supported by preparing and conducting expert interviews.

* This contribution was awarded the best paper award of the track "Business Process Management in the Digital Age" and nominated for the best paper award (Claudio Ciborra Award) of the overall conference ECIS 2021.

Table 1. Overview of the research contributions

2.2 Framework of the Research Contributions

Due to technological progress and individuals' and organizations' increasing use of digital solutions, IS research has established itself as an independent and mature discipline with specific methods and perspectives in the research landscape (Baskerville and Myers 2002). IS research can be divided into behavioral and design science (Hevner et al. 2004; Österle et al. 2011). Behavioral science focuses on analyzing and explaining the cause-and-effect relationships of real-world phenomena in sociotechnical systems. It generates and tests theories to explain reality and provides descriptive knowledge. Conversely, design science aims to generate prescriptive knowledge in means-end relationships to solve problems (Venable 2006; Hevner 2007). Artifacts such as constructs, methods, models, or instantiations are created for effective and efficient problem solving. Nunamaker clarifies in an interview with Winter (2010, p. 322) that a purely behavioral view does not align with the IS discipline's character and is no driver for business innovation:

"You cannot restrict yourself to explaining existing concepts and systems while everyone wants to hear about what is new and what is coming next."
Jay F. Nunamaker, Regents Professor and Director of the Center for Management of Information at the University of Arizona

However, the two streams are not contrary but can complement each other (Nunamaker and Briggs 2012). The design science research (DSR) approach combines the two streams by contributing artifacts to solve a real-world problem (problem space) and simultaneously developing them based on a sound knowledge base (solution space). Hevner (2007) describes DSR as an artifact-development process that involves three cycles simultaneously (cf. Figure 1).

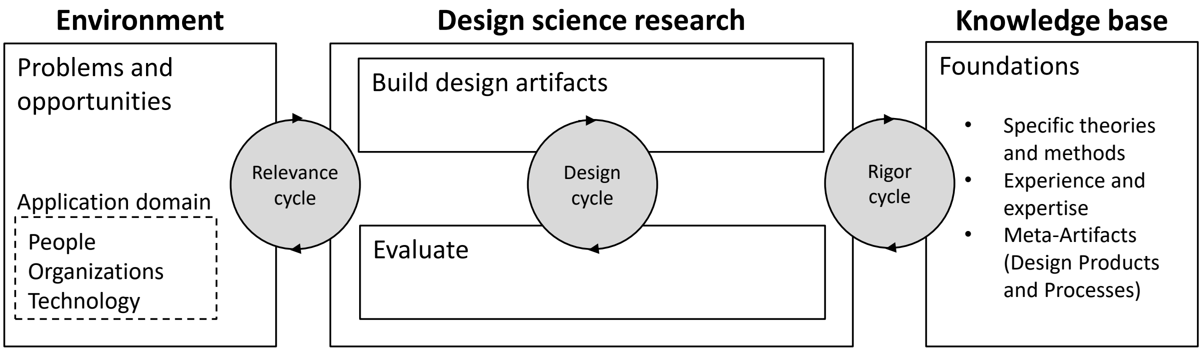

Figure 1. Design science research cycles based on Hevner (2007)

The relevance cycle "bridges the contextual environment of the research project with the design science activities"(Hevner 2007, p. 88). This process ensures that the problem comprises a real-world problem, eliciting the artifact requirements based on real stakeholders, organizations, and technical systems (cf. Depietro et al. 1990; vom Brocke et al.

2020). Developed artifacts can be simultaneously tested in field studies to obtain valid feedback regarding their usefulness. The rigor cycle uses the knowledge base so that artifacts are generated using existing (kernel) theories, methods, and (design) experience. The knowledge gained through the artifacts' development can be recirculated to expand the knowledge base for future research. The central design cycle is an iterative process that develops artifacts and subsequently evaluates them. Different aspects, such as suitability, usability, usefulness, or artifact efficiency, can be evaluated at different development stages (Venable et al. 2016). While Hevner (2007) primarily presents the framework of DSR projects, Peffers et al. (2007) focus on the iterative character and the detailing of individual build-evaluate cycles.

Using the DSR approach, a VR artifact for operational process design (the VR-BPM system) was created as a central part of this cumulative dissertation. As per most DSR projects, the artifact's development and evaluation involved multiple stakeholders (vom Brocke and Lippe 2010). During the three-and-a-half-year research project SoDigital of the German Federal Ministry of Education and Research, a VR software provider and three SMEs served as development and application partners.[2] The project's goal was to enable and motivate SMEs and their employees to use a VR system to model, analyze, and improve their business processes along the operational BPM cycle (see Figure 2).

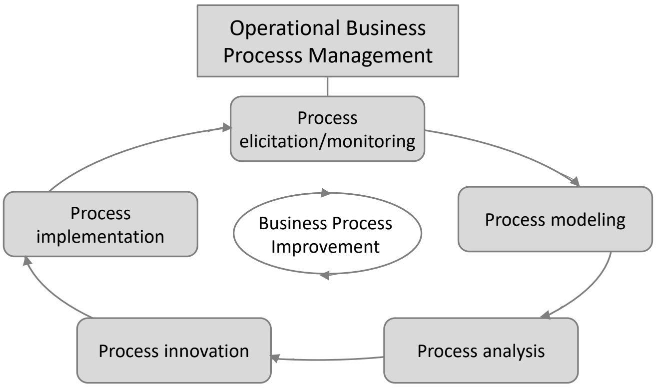

Figure 2. Business process management cycle based on Dumas et al. (2018)

The main objectives of the improvements for the SMEs were implementing digital solutions, improving employee satisfaction, and reducing process cycle times. The three SMEs were particularly well-suited as application companies since their low organizational embedding and built-up expertise in BPM precisely reflected the motivational challenges (cf. Liao and Barnes 2015). Thus, the rigor cycle drew primarily on these three SMEs, enabling requirements to be identified and field studies to be conducted. Furthermore, the organizational embedding and VR-BPM system implementation were investigated so that a second artifact, the XR-Canvas, was developed. During the project, seven contributions (A–

[2] More information about the research project can be found here: www.sodigital.uni-osnabrueck.de

G) were selected to enhance the VR-BPM system's scientific positioning, development, and evaluation. Additionally, Contribution H promotes the implementation and presents the extended reality (XR)-Canvas as a specific artifact for VR implementation.

Figure 3 illustrates how the respective contributions within an extended DSR framework contributed to the VR-BPM artifact's development and implementation and which contributions answer the respective RQs. The two Contributions A and B serve as an initial combined feasibility study to answer RQ1. Contribution A unfolds the problem space by deriving the motivating challenges in BPM (cf. Section 1) and subsequently presents VR literature-based potentials to address these challenges (Straatmann et al. 2022). Contribution B initially presents an overview of existing research on virtual-world process modeling with a concept matrix according to Webster and Watson (2002). Subsequently, a comparison study investigates whether VR in BPM activities has advantages or disadvantages compared to conventional BPM tools and, thus, provides descriptive knowledge (Pöhler and Teuteberg 2021).

Based on the promising results of the Contributions A and B, the development and evaluation of an interactive, highly immersive, and user-centered artifact for process design, the VR-BPM system, occurred in order to answer RQ2. Contribution C expands the descriptive knowledge of the solution space by determining user requirements and preferences for VR hardware design and interaction via a conjoint analysis (Schuir et al. 2022). Contributions D and E connect the problem and solution space by deriving design principles for the VR-BPM system. The development of design principles is guided by Kahn's (1990) kernel theory, which provides factors for employee engagement at work, and are formulated according to Gregor et al.'s (2020) anatomy of a design principle. The instantiation of an interactive VR system occurred afterward. In this context, Contribution D explicitly presents one build-evaluate cycle (Pöhler et al. 2020), while Contribution E (Pöhler et al. 2021) presents several iterative cycles according to Peffers et al. (2007). The Human Risk and Effectiveness strategy from the Framework for Evaluation in Design Science (FEDS, Venable et al. 2016) guided the evaluation, which follows a more application-oriented and less technical evaluation strategy. In addition to the suitability already evaluated in Contribution B, the VR-BPM system's completeness, usability, and usefulness were tested in different settings. To test for the VR-BPM system's usefulness, several field studies were conducted in the SMEs, so the artifact could achieve the highest evaluation quality by meeting the three realities (real tasks, real systems, real users) according to Sonnenberg and vom Brocke (2012). Finally, Contributions D and E provide prescriptive knowledge through structured design principles for interactive, highly immersive, and user-centered IS (Pöhler et al. 2020; Pöhler et al. 2021). Based on the findings of the design-oriented contributions, Contributions F and G address the economic impact of an investment in the VR-BPM system. The focuses of these additional evaluations extend beyond traditional DSR evaluations of IS artifacts, as they simulate long-term effects on organizations (cf. Sonnenberg and vom Brocke 2012). In Contribution F, the long-term organizational benefits applying the VR-BPM system were determined by means of utility effect chains according to Schuman and Linß (1993). Based on these findings, Contribution G first develops a DSR supported utilization-based cost-benefit analysis (CBA) method based on Sassone and Schaffer (1978), evaluates it by expert interviews and subsequently applies the CBA to the VR-BPM system. Finally, both contributions demonstrate under which organizational conditions an investment is economically worthwhile (Pöhler and Teuteberg 2022; Pöhler and Teuteberg 2023).

The XR-Canvas was developed in Contribution H (Pöhler et al. 2023) to enable VR implementation in organizational structures meaningfully and to answer – supported by findings of Contributions F and G – RQ3. This tool aims at a holistic view of VR projects and their implementation from a technical, organizational, environmental, and individual (TOEI, Depietro et al. 1990) perspective and was developed in a separate, smaller design-oriented project. Literature reviews, according to vom Brocke et al. (2009), and semi-structured expert interviews (Gläser and Laudel 2010), were used to build and evaluate an artifact intended to support the important dissemination of VR (and the similarly disruptive augmented reality (AR) technology) into practice. In doing so, the XR-Canvas addresses organizational ambidexterity, enabling organizations to achieve technological progress while preserving their productivity (cf. Schneeberger and Habegger 2020).

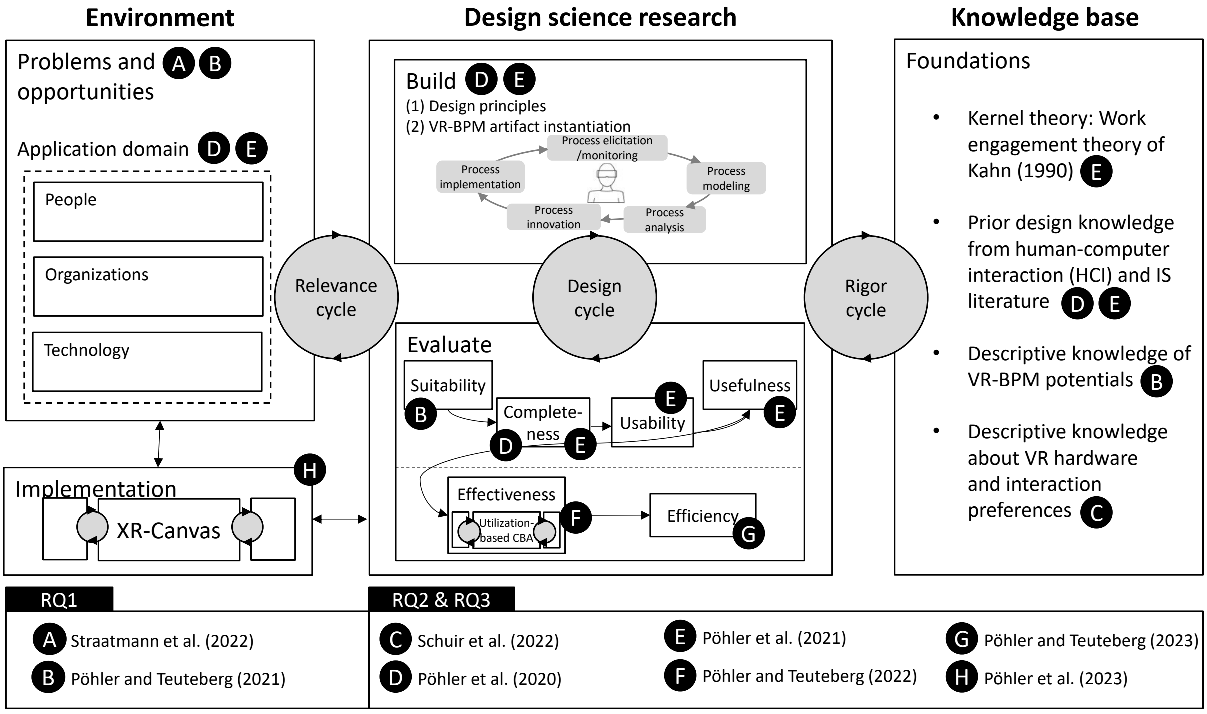

Figure 3. Classification of the contributions adapted from Hevner (2007)

2.3 Spectrum of Methods

For exploring the symbiosis of BPM and VR from design and behavioral science perspectives, the IS discipline offers quantitative and qualitative research methods (Kaplan and Maxwell 2005). On the one hand, quantitative research relies primarily on numerical data and confirms or disproves cause-and-effect relationships through statistical considerations (Burton-Jones and Lee 2017; Recker 2013). On the other hand, qualitative research relies on incorporating, analyzing, and drawing conclusions from non-numerical data, promoting the exploration of unknown fields of research(Recker 2013).

In this cumulative dissertation, the methods complement each other. For example, based on quantitative questionnaire analyses of constructs (Contribution B), causality can be achieved via qualitative in-depth interviews or focus group discussions (Contribution E). Conversely, how to design quantitative surveys can be based on previously performed qualitative expert interviews (e.g., Contribution C). The applied combination of the two method streams forms a mixed-methods approach (Venkatesh et al. 2013; Creswell and Creswell 2017). The advantage of combining diverse qualitative and quantitative methods is that the weaknesses and limitations of individual research methods can be countervailed by the strengths of other methods (Creswell et al. 2003). In addition, data triangulation is undertaken by examining issues and evaluating findings from different perspectives to obtain a holistic view of sociotechnical innovation (Recker 2013). Table 2 summarizes the methods used in the individual contributions, including their theoretical foundation.

	Research method	Contribution								Reference(s)
		A	B	C	D	E	F	G	H	
Qualitative	Literature review	x	x	x	x	x	x	x	x	vom Brocke et al. (2009); Webster and Watson (2002)
	Qualitative content analysis	x	x	x		x	x	x	x	Mayring (2004)
	Reverse brainstorming		x							Williams and Smith (1990)
	Experimental case study		x	x	x					Recker (2013)
	Experimental field study				x	x				Klein and Myers (1999)
	Expert interviews			x		x	x	x	x	Gläser and Laudel (2010); Baskerville and Myers (2002)
	Workshops, Focus groups				x	x	x			Morgan (1998); Myers and Newman (2007)
	Prototyping				x	x		x	x	Hevner et al. (2004)
	Utility effect chains						x	x		Anselstetter (1984); Schumann and Linß (1993)
Quantitative	Comparison study (Mann-Whitney-U Test, t-test)		x							Cohen (2013)
	Survey			x						Recker (2013)
	Conjoint analysis			x						Green and Srinivasan (1978)
	Cost-benefit analysis							x		Sassone and Schaffer (1978)
	Monte-Carlo Simulation							x		Savvides (1994)

Table 2. Overview of research methods applied

All methods were applied within the extended DSR framework (Figure 3), focusing on the artifacts' framing, development, or evaluation (A–G: VR-BPM system, H: XR-Canvas). Each publication started with a systematic literature review, according to vom Brocke et al. (2009), to position the publication meaningfully within the research field and outline the existing research gap. The five-phase model according to vom Brocke et al. (2009) was applied in each contribution to obtain a rigorous and ideally complete overview of the research field. The operational application of the other research methods is presented in detail in the individual Contributions A–H.

3 Synthesis of the Research Contributions

3.1 VR in BPM Activities

The potential and suitability of VR for BPM activities were first reviewed with a combined feasibility study, carried out in Contributions A and B, to guarantee a demand-driven design of IT artifacts. For this purpose, the research area was initially reviewed regarding previous work. With the help of a literature search according to vom Brocke et al. (2009) and the presentation of related work in a concept matrix according to Webster and Watson (2002), the research gap could be clarified and the use case embedded. Table 3 presents the prior work that has explored the design of processes in virtual worlds. The use of head-mounted display VR is increasingly replacing desktop solutions (Pöhler and Teuteberg 2021). However, only Thies et al. (2019) simultaneously link process modeling and replicas of real-work environments. However, they follow a completely different approach by generating VR training in immersive environments based on existing BPM models. Therefore, it became apparent that no artifacts for interactive, collaborative and contextualized process design in head-mounted display-generated realistic-work environments had been created yet.

Author	**Technic**		**Content focus**					**Virtual World**		
	VR	**Desktop**	**Visualization**	**Elicitation**	**Modelling**	**Under-standing**	**Analysis**	**Abstract**	**Realistic (no context)**	**Realistic (context)**
Leyer et al. (2021)		x	x			x				x
Zenner et al. (2020)	x		x		x	x		x		
Thies et al. (2019)	x				x					x
Leyer et al. (2019)		x	x			x				x
Abdul et al. (2019)		x	x		x					x
Oberhauser and Pogolski (2019)	x		x		x			x		
Roldán et al. (2019)	x		x		x			x		
Oberhauser et al. (2018)	x		x		x			x		
Andres et al., 2018)	x				x	x		x		
Poppe et al. (2017)		x					x	x		
Harman et al. (2016)		x		x	x					x
Aysolmaz et al. (2016)		x				x				x
Kathleen et al.(2014)		x	x						x	
Brown et al. (2014)		x		x	x				x	
Weichhart et al. (2014)		x				x			x	
Poppe et al. (2013)		x		x	x			x		
Guo et al. (2012)		x	x	x						x
Brown et al. (2011)		x			x				x	
West et al. (2010)		x			x				x	

Table 3. Concept matrix of BPM in virtual worlds based on Pöhler and Teuteberg (2021)

As guided by Sonnenberg and vom Brocke (2012), the following feasibility study aimed to ensure that no unnecessarily high efforts are expanded on prototyping if the potential and suitability of VR are low for BPM activities. An integrative literature search was first conducted in Contribution A (Straatmann et al. 2022) to determine the potential. Based on these findings, a 2D BPM versus VR-BPM comparison study was conducted in Contribution B to provide valuable insights for answering RQ1 (Pöhler and Teuteberg 2021).

3.1.1 Potentials of VR for overcoming BPM Challenges

Based on the challenges of current BPM activities, VR's potential to overcome these barriers was to be determined in Contribution A by applying an integrative literature review guided by vom Brocke et al. (2009). For this purpose, 52 sources were considered relevant: they describe VR potential and benefits in organizational and real-world use cases. By applying a qualitative content analysis according to Mayring (2004), 13 characteristic-related and 10 effect-related VR advantages for BPM activities were identified. Characteristic-related benefits represent the technical lens on VR, while effect-related benefits include the personal or organizational level effects resulting from the use of and interaction with VR (Straatmann et al. 2022).

Experts in VR and BPM mapped the individual advantages to current, motivating challenges in BPM activities (see Section 1). The overall result is presented in Figure 4, where characteristic-related and effect-related VR advantages are linked to the motivating problems of consistency, automated fiction, project management, and motivation.

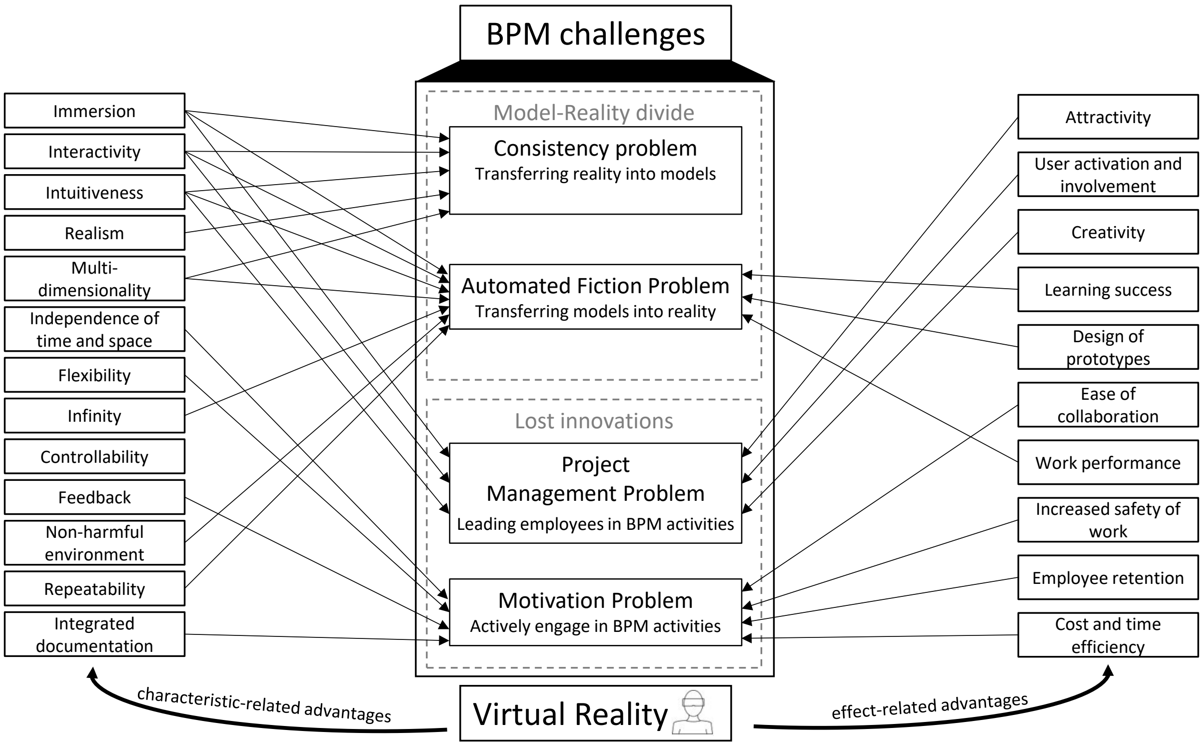

Figure 4. Potential of VR for overcoming BPM challenges based on Straatmann et al. (2022)

Consequently, VR has wide-ranging potential for overcoming current BPM activity barriers (Straatmann et al. 2022). VR can contribute to transforming mental models into formal models to overcome the model-reality divide, especially through characteristic-related advantages like immersive spatial contextualization and the intuitiveness and realism of VR. One way to mitigate the automated fiction problem is to allow processes to be developed and tested in secure, flexible, and multi-dimensional environments before implementation. In addition, the lost innovation caused by low employee engagement can be overcome by motivating interactive use and creativity support for VR. Subsequently, simplified, barrier-free collaboration and integrated documentation can contribute to overcoming the project-management problem.

3.1.2 Suitability of VR for BPM Activities

A comparative study of using VR for BPM activities was conducted to investigate the theory-based potential experimentally in Contribution B (Pöhler and Teuteberg 2021). The goal was to investigate the general suitability of VR compared to conventional BPM instruments. A Unity-based fictional industrial hall was the VR environment in this proof-of-concept study (cf. Figure 5, 1). The only interaction with the VR environment was the locomotion by using the teleport function through the hall. Twenty linear process steps of a fictional picking process were visualized at their execution locations with their executing roles (sales, picking). The 2D comparison representation was a BPMN process printed on paper. It was supplemented by numbering at the execution locations in a bird's-eye view (cf. Figure 5, 2).

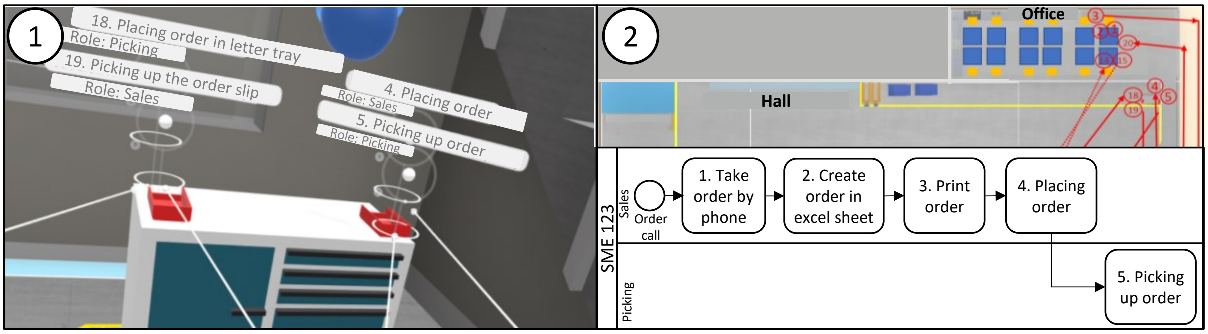

Figure 5. VR-BPM and 2D-BPM conditions based on Pöhler and Teuteberg (2021)

Twenty-eight participants were recruited for the experiment, 15 operating in the 3D VR environment and 13 in the conventional 2D perspective. No significant differences were found regarding sex ($U = 71$, $Z = -1,442$, $p = .246$), experience in process modelling ($U = 79$, $Z = -.881$, $p = .414$) and experience with the industry ($U = 86$, $Z = -.547$, $p = .588$) between the conditions (Pöhler et al. 2021). The aim was not to perform active modeling but to identify weak points in the process based on process models already generated in the respective environments (process analysis). The number and type of weak points identified per environment (weak point score = WPS) were subsequently analyzed using Mann-Whitney-U (MWU) test and t-test (TT, Cohen 2013; Table 4).

WPS	Mean VR	SD VR	Mean 2D	SD 2D	Test	Results
Overall	9	1.93	8.38	3.12	TT	t(26) = .637, p = .53, not significant
Individual Process Step	5.73	2.28	4.15	2.41	TT	t(26) = 1.780, p = .09, not significant
Process Group	2.47	1.36	3.23	1.17	MWU	U = 66.5, Z = -1.481, p = .15, not significant
Overall Process	0.8	0.78	1	0.58	MWU	U = 81, Z = -.84, p = .45, not significant
ICT	3.33	1.11	2.92	1.32	MWU	U = 83.5, Z = -.664, p = .53, not significant
Process Route	1.93	1.22	1.92	1.5	MWU	U = 93, Z = -.218, p = .84, not significant
Workflow	2.73	1.39	2.92	1.94	TT	t(26) = -.301, p = .77, not significant
Security	0.33	0.62	0.15	0.38	MWU	U = 85.5, Z = -.776, p = .56, not significant
Sustainability	0.4	0.51	0.23	0.44	MWU	U = 81, Z = -.939, p = .44, not significant
Automation	0.13	0.35	0.077	0.28	MWU	U = 92, Z = -.473, p = 1, not significant

Table 4. WPS results in the two conditions (Pöhler and Teuteberg 2021)

In addition, participants completed a questionnaire after the experiment to answer constructs aimed at promoting motivation (flow state (FS), cognitive load (CL), presence (Pr), and usability (Us)) to encourage in BPM activities. MWU and t-tests were applied to determine group differences, leading to the results shown in Table 5 below.

Construct	Mean VR	SD VR	Mean 2D	SD 2D	Test	Results
FS - Absorption	5.4	0.88	5.39	1.073	TT	t(26) = .042, p = .97, not significant
FS - Fluency of Performance	5.48	0.98	5.28	1.072	MWU	U = 91, Z = -.302, p = .76, not significant
CL - Intrinsic Load	2.29	1.02	1.97	0.89	TT	t(26) = .863, p = .4, not significant
CL - Extraneous Load	1.97	0.86	2.08	1.02	TT	t(26) = -.311, p = .76, not significant
CL - Germane Load	3.06	1	4.08	1.31	MWU	U = 56, Z = -1.916, p/2 = .028, significant
CL - Overall Load	5.27	0.96	5.08	1.32	MWU	U = 97, Z = -.25, p = 1.0, not significant
Pr - Spatial Presence	5.03	1.07	3.46	0.92	MWU	U = 27, Z = -3.258, p = .001, significant
Pr - Attention Allocation	6.15	0.77	5.25	0.76	MWU	U = 37, Z = -2.800, p = .004, significant
Pr - Visual Spatial Imagery	5.27	1.35	5.06	1.69	TT	t(26) = .364, p = .72, not significant
Us – Perceived Usefulness	5.9	0.8	5.97	0.75	MWU	U = 93.5, Z = -.186, p = .861, not significant
Us – Perceived Ease of Use	5.23	0.7	5.31	0.96	MWU	U = 91.5, Z = -.278, p = .79, not significant
Us - Satisfaction	6.19	0.73	5.14	0.86	MWU	U = 33.5, Z = -2.962, p = .002, significant

Table 5. Construct results in the two conditions (Pöhler and Teuteberg 2021)

Table 4 results did not provide significant differences in the amount of detected weak points. Despite the lack of significance of these results, this does not mean, as Amrhein et al. (2019) and more than 800 signatories confirm, that this does not indicate "no difference" or "no effect." Rather, the results indicate tendencies that can be usefully built upon. More weak points tended to be found in VR related to safety-relevant aspects and individual process steps. However, in 2D more weak points of the overall process were detected.

Table 5 showed no significant differences in the flow state of the constructs. The VR environment showed higher satisfaction values, ease of use, and spatial presence. In the 2D environment, higher values were obtained for the germane load. With consistent quality (quantity of detected weaknesses), VR mainly proves advantages in satisfaction while performing process-management activities, which can get over low employee motivation to engage in BPM activities (Pöhler and Teuteberg 2021). Since one main aim of using VR for BPM is overcoming low motivation challenges, the general suitability of VR for process modeling activities could be demonstrated and encouraged for developing an interactive VR system.

3.2 Design and Evaluation of the VR-BPM System

Based on the promising preliminary studies, the focused development of the VR-BPM system was done by applying the DSR approach and to answer RQ2. The problem space, largely known through the feasibility and suitability study, was first complemented by the solution space to generate concrete design principles for the VR artifact. The solution space was created by incorporating existing theories and methods for employee motivation from Contribution E, user preferences for hardware design and selection from Contribution C, and existing design knowledge from literature and practice (Contributions D and E). The VR-BPM system's subsequent development and evaluation was based on the combined findings from Contributions D and E.

3.2.1 Creation of the Solution Space

In the rigorous derivation of design principles, integrating a central guiding theory, the kernel theory, is recommended (cf. vom Brocke et al. 2020). In particular, to counteract the motivation problem for BPM participation in organizations, developing the VR artifact was based on the psychological conditions of personal engagement and disengagement at work, according to Kahn (1990). Three components are required to generate engagement: psychological meaningfulness, safety, and availability (Kahn 1990). Employees experience meaningfulness in their jobs when incentive-creating elements are incorporated into their tasks or if they see obvious progress in executing their tasks. Safety can be created if employees do not have to experience negative consequences for personal commitment and if interpersonal relationships are strengthened. Psychological availability is achieved if employees can use their psychological resources without distraction to show commitment in the work environment (Kahn 1990).

In addition to incorporating the central kernel theory, the knowledge base was expanded by querying user preferences for VR hardware in Contribution C. Since user preferences are central in technology adoption, hardware preferences serve as input from the knowledge base in generating rigorous design principles and instantiating them (Lee et al. 2003). Using a selection-based conjoint analysis according to Green and Srinivasan (1978), the VR hardware preferences of 225 study participants were obtained by a survey. Interviews with eight VR experts conducted beforehand facilitated forming of valid attributes and associated specification levels. In the following survey, the participants (average age = 20.94 years; 59.31% male, 40.69% female) were asked to decide on their preferred configuration in 17 selection situations with differing attribute characteristics. The overall pattern shown in Table 6 emerged.

Attribute	Level	Part-Worth Utility	Relative Importance
Price	€400	3.750	28.01%
	€650	.771	
	€900	−4.521	
Interaction	Controllers	−3.342	21.29%
	Controllers with finger tracking	.286	
	Hand tracking	3.057	
Display quality	Low	−2.021	20.47%
	Medium	−1.449	
	High	3.470	
Privacy policy	Facebook login	−2.093	17.54%
	Oculus login	−0.534	
	Customizable	2.627	
Type	Tethered	−0.792	12.05%
	Standalone	.792	
Note: averaged preferences are presented in the appendix of Contribution C			

Table 6. Preferences for VR hardware based on Schuir et al. (2022)

The results show that in addition to price, interaction, and display quality are considered important in purchasing and using VR systems. Hand-tracking allows users to interact with a head-mounted display-generated VR alone. While controllers are correspondingly less desired by users, they offer advantages in use due to their wider interaction options via fixed button assignments (De Giorgio et al. 2017). Moreover, whether the VR is a stand-alone or computer-coupled (tethered) solution is not as decisive in the selection; however, a stand-alone solution is preferred. Data-protection measures are not to be neglected, with users preferring customizable software privacy policies. Free text fields were evaluated via a qualitative content analysis, according to Mayring (2004), to determine a clearer picture of the reasons for prioritizing or rejecting attributes. Figure 6 shows the reasons, classified according to the respective product attributes.

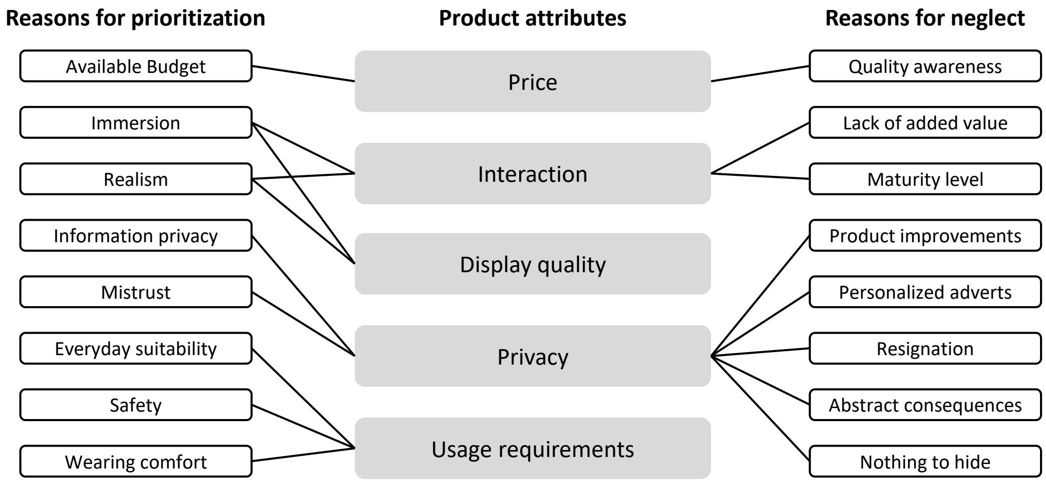

Figure 6. Reasons for prioritizing and neglecting VR attributes based on Schuir et al. (2022)

Based on the results illustrated in Figure 6, realism and immersion should be kept high with the most mature and modern hardware solutions for displays and controllers. Wearing comfort should also be ensured with hardware for practical use in everyday working life. Additionally, safety should be ensured by eliminating tripping hazards (e.g., cables). Data protection also contributes in designing VR systems, as it is important to ensure that privacy guidelines are complied with in the software design and that users are informed before application (Schuir et al. 2022). The Table 6 and Figure 6 findings on user preferences were incorporated into the subsequent preparation of the design principles and especially in the following instantiation.

In addition, the solution space was extended based on existing human-computer interaction (HCI) and IS literature for the design of highly immersive interactive information systems. For example, findings from Vogel et al. (2021), the first to publish prescriptive knowledge on designing multi-user VR systems at highly ranked IS conferences (ECIS), were incorporated. Moreover, with market research, innovative solutions from factory planning, process planning, and workplace design were screened in Contributions D and E to incorporate the latest discoveries and guarantee the incorporation of current state of the art.

3.2.2 Design and Instantiation of the VR-BPM System

Design principles aim to overcome problem-space challenges using knowledge from the solution space (Gregor and Hevner 2013). It is advisable to first derive meta-requirements for the technical system based on the challenges to derive the design principles systematically. Consequently, based on the findings from the problem-and-solution space and informed by Sutton and Arnold (2013), a workshop was conducted with experts from VR and process management. Fifteen central issues (I) resulted in 14 meta-requirements

(MR) for the technical system. These meta-requirements were aggregated so that four final design principles emerged (cf. DP1-DP4, Figure 7). The four design principles follow the anatomy of a design principle according to Gregor et al. (2020), as the formulation describes the goal and user, context, mechanism, and rationale of each design principle. The derivation of the design principles based on contributions D and E is outlined in the following.

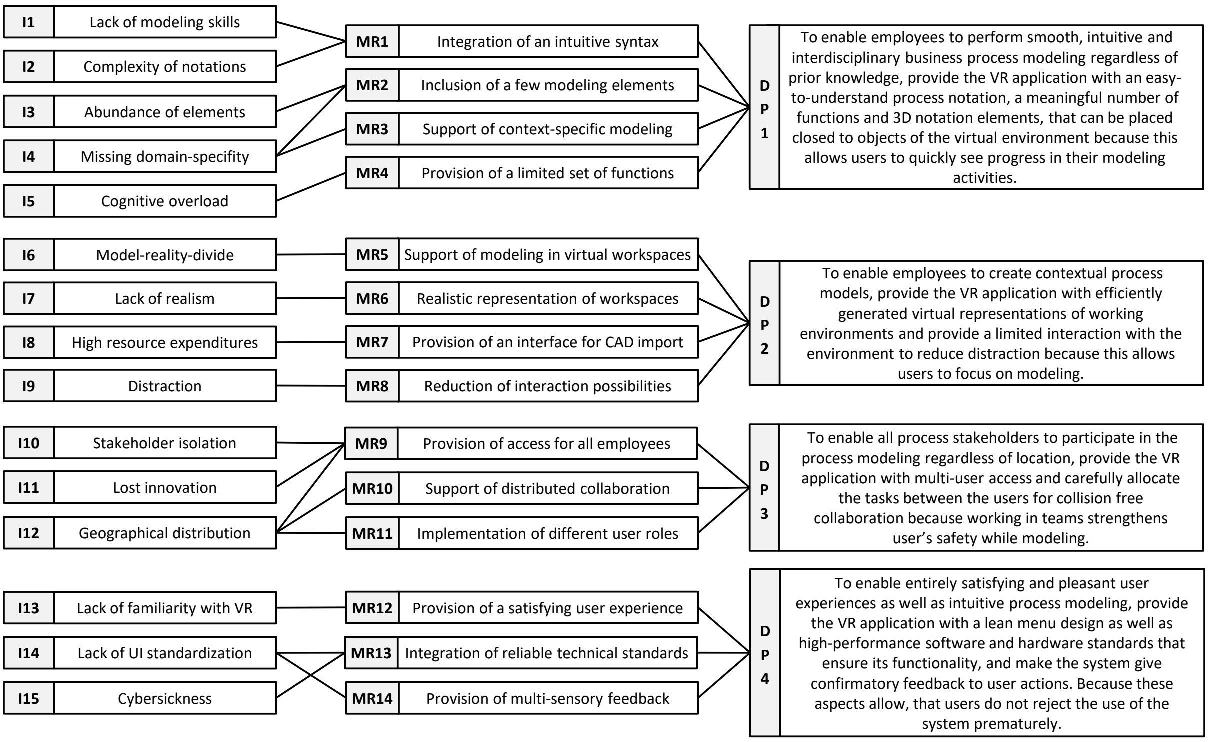

Figure 7. Derivation of design principles based on Pöhler et al. (2021)

Employees engage in work when experiencing meaningfulness as knowledge givers and takers (Kahn 1990). Therefore, an intuitive process-modeling kit to actively engage employees forms **DP1** (Pöhler et al. 2021). Inexperienced modelers have difficulty in transforming mental models into semiformal process models (Pinggera et al. 2015). Therefore, the VR system should provide a process notation containing an adequate intuitive syntax (MR1). In addition, an overloaded amount of notation elements in traditional process notations impedes collaborative modeling as only a small proportion of BPMN is operationally applied in organizations (Recker 2010). Consequently, the artifact should integrate a manageable number of equally understandable modeling elements (MR2). Linking 3D elements and real-world objects facilitates understanding process models (Zenner et al. 2020). Therefore, the artifact should allow 3D notational elements to be placed near objects within virtual replicas (MR3; Leyer et al. 2021). Common modeling tools include features like analysis and simulation (Riemer et al. 2011; Elstermann et al. 2022), to generate additional information. To fulfill process analysis, an evaluation tool should enable limited rating functions (MR4). Kahn (1990) also describes the negative impacts of distraction on psychological availability. Consequently, **DP2** refers to a non-distracting and inspiring environment (Pöhler et al. 2021). The model-reality divide negatively affects modeling engagement and the subsequent process quality (Schmidt and Nurcan 2009). Therefore, the VR-BPM system should allow users to model within virtual work-environment replicas (MR5; Brown and Cliquet 2008), as this function enables greater contextualization. Nevertheless, the risk still exists that VR's realism degree is too low for users to intuitively draw a connection to reality (Van Wyk and De Villiers 2009). Therefore, the environment in virtual twins must be sufficiently realistic (MR6, Metzger et al. 2017) for overcoming these barriers. Designing realistic virtual environments incurs significant 3D modeling effort (Hilfert and König 2016). Consequently, the VR system should support efficient VR environment creation by integrating adequate tools and interfaces (MR7). To avoid distractions, Metzger et al. (2017) recommend little interaction with the VR environment during active task execution (MR8). Interpersonal and social relationships can enhance psychological safety (Kahn 1990). Therefore, **DP3** addresses collaboration (Pöhler et al. 2021). Process models often contain explicit knowledge, while tacit knowledge is not adequately documented (Bider and Perjons 2015). Furthermore, process actors increasingly work in geographically dispersed locations due to increasing globalization (Vogel et al. 2021). Consequently, the artifact must provide access for employees at different organizational levels (MR9) and foster remote collaboration (MR10; Forster et al. 2013). Multi-user VR can overcome these problems through social collaboration enabled by virtual spaces (Vogel et al. 2021). However, the delamination of tasks and functions of distributed users presents a critical aspect (Brown et al. 2011) in collaborative modeling, which strict role management can solve (MR11). A clear user interface (UI) forms **DP4** to avoid a premature rejection of the system (Pöhler et al. 2021). The UI constitutes a critical task in VR (Metzger et al. 2017), as a non-intuitive button layout or complicated navigation can lead to confusion and rejection of the technology (Frommel et al. 2017). Standardized UIs for VR interaction remain a challenge (Anthes et al. 2016), and users still report symptoms like simulation sickness (Saredakis et al. 2020). Therefore, the goal is to take care for a satisfying user experience based on high comfortability (MR12) and also using reliable and modern technical standards (MR13; Vogel et al. 2021). Additionally, a lack of response when selecting actions can lead to early rejection of disappointed users (Hoppe et al. 2018), which the provision of multisensory feedback can solve (MR14).

By applying an agile development process, according to Highsmith and Cockburn (2001), the design principles could be instantiated, resulting in a VR artifact based on four components. The solution concept in Figure 8 presents these four components and their relationships after all evaluation cycles (see Section 3.2.3) in detail. In the following, the four components are described in detail (cf. Pöhler et. al 2021).

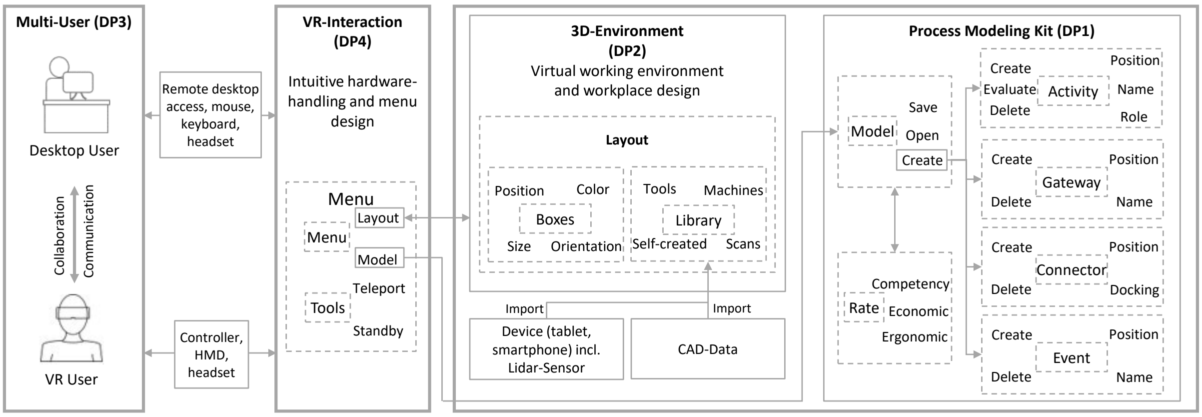

Figure 8. Solution concept of the VR-BPM system based on Pöhler et al. (2021)

3D-Environment: Using simple, scalable, cubic geometries addresses the need for an immersive and efficiently generated 3D environment. This provides the basis for placing process steps where they are executed in reality. To build the VR environment as a digital twin, Computer-Aided Design (CAD) models of production halls can be imported into the VR environment. Integrating process-relevant objects (e.g., machines, tools) is enabled by true-to-scale point clouds generated by Light Detection and Ranging (LiDAR) scans (cf. Figure 9). For standard elements, such as forklifts, assembly tables, or office equipment, elements from an extensive integrated 3D library can be called up.

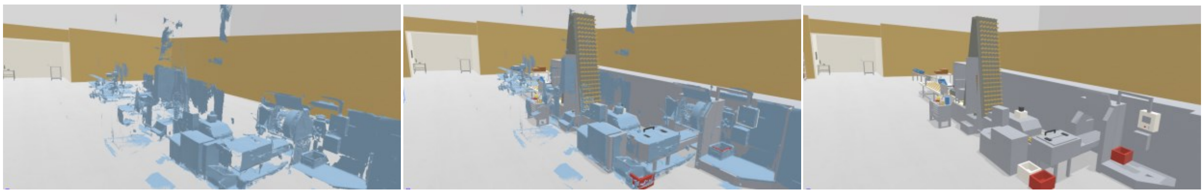

Figure 9. VR environment generation using LiDAR-Scans (Pöhler et al. 2021)

VR-Interaction: Based on the user preference study's findings (Contribution C), the system was designed to enable a high level of interaction by using modern VR hardware and integrating sensible button assignment. High-resolution, head-mounted displays and stand-alone devices, such as the Oculus Quest 2, also ensured a highly immersive and barrier-free experience. In addition, the teleport function enabled quick locomotion (Figure 10, d). The menu was divided into tabs where icons could be intuitively selected to choose actions (Figure 10, a-c). This provides a clear and quickly manageable user experience and precludes mental overload. Moreover, users receive multisensory feedback via vibration and lighting effects.

Process Modeling Kit: The process-modeling kit is based on BPMN logic. The most frequently used elements can be called up and generated via the trackpad (Figure 10, f), and activities, events, and gateways can be generated with it. In addition, instead of displaying the roles in swimlanes, they are assigned to activities (Figure 10, e). The linking is made by using rings below the elements (Figure 10, e). and by connectors, which light up as arrows and automatically dock to other elements (Figure 10, h, i). Text for labeling the elements is entered with a VR keyboard (Figure 10, g). An evaluation can be made on a 1–5 scale per competency characteristic (Figure 10, j) to rate individual process steps regarding the competencies required. Ergonomic aspects can also be evaluated with notes and rating scales (Figure 10, k).

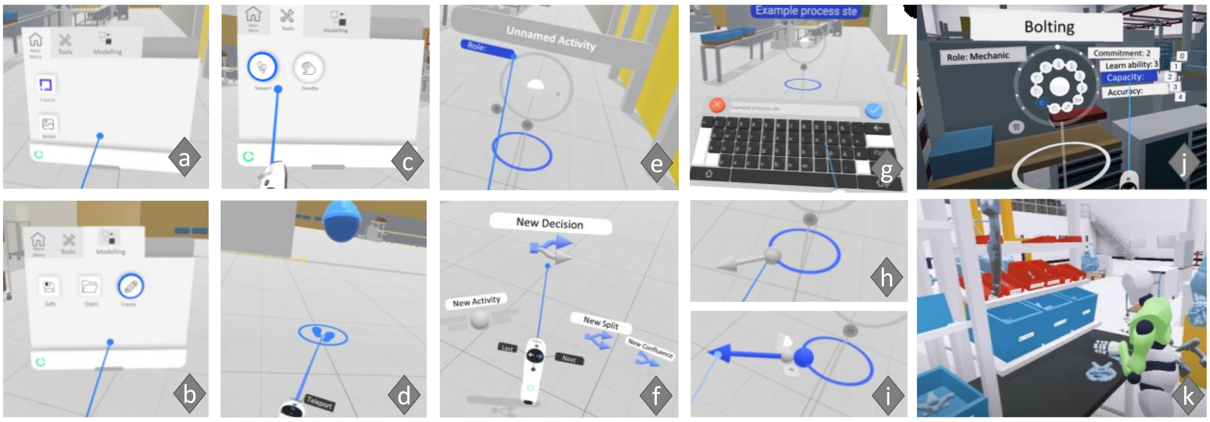

Figure 10. Process modeling kit based on Pöhler et al. (2021)

Multi-User Access: The VR user's view is extended by a desktop version for a second user, who can operate it with a mouse and type by keyboard. Multiple users are therefore able to model at the same time in the environment. To enable communication over greater spatial distances, users can communicate via headsets. Desktop users can assist with text entry so the VR users can concentrate on modeling processes. Similarly, desktop users can interact with VR users by using markers as hints in the virtual twin. Additionally, user rights are clearly divided, which supports that they do not obstruct each other during modeling.

3.2.3 Evaluation of the VR-BPM System

Evaluation cycle 1: Completeness

Following the feasibility study with the first static prototype from the comparative study, an interactive prototype for active process modeling and analysis in virtual work environments was developed in Contribution D. Consequently, the modeling of an exemplary three-step-process with the first instantiation of the process-modeling kit was tested in a fictional virtual office building. In functional tests with eight employees of a VR software company, as recommended by Kontio et al. (2004), the views of different stakeholders, such as sales, development, and project management, were integrated. In teams of two, processes consisting of three activities should be named, connected, and the role assigned (cf. Figure 11). The desktop user served only to assist and communicate verbally with the VR user.

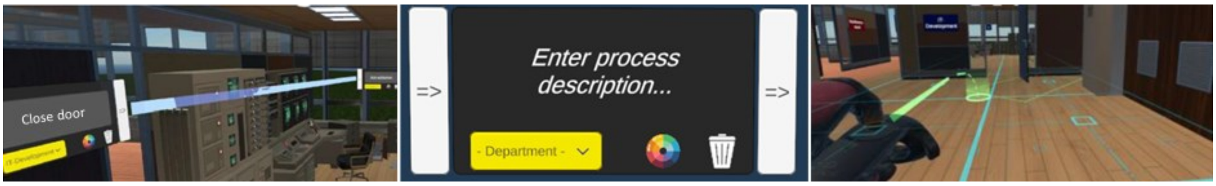

Figure 11. Interactive VR-BPM system in the first evaluation cycle based on Pöhler et al. (2020)

A focus-group discussion aiming at completeness was conducted with the participants. Based on the feedback, the following changes were made: the process modeling kit was extended by gateway elements to map non-linear processes. Integration of tools for environment design (create, position, and orient boxes) and the storage and call-up of library elements were enabled to place the processes individually in digital twins, not in standard buildings. The desktop user was given text input rights and markers to make text entry more efficient and help with orientation. A graphical revision of the menu design, modeling kit, and teleport occurred to make the VR experience more vivid (Pöhler et al. 2020).

Evaluation Cycle 2: Usability

After the expansion and refinement, the focus was on the process-modeling kit's usability as a central VR artifact element in Contribution E. For this purpose, user tests were conducted using Wharton et al.'s (1994) cognitive walkthrough method, which in particular aims to ask usability experts to perform and try predefined tasks, which increase in difficulty (Mahatody et al. 2010). Next, their reasoning is recorded to solve interaction and UI design problems. Six experts identified and mentioned the problems during the performance, which were subsequently classified and ranked in severity (cf. Figure 12).

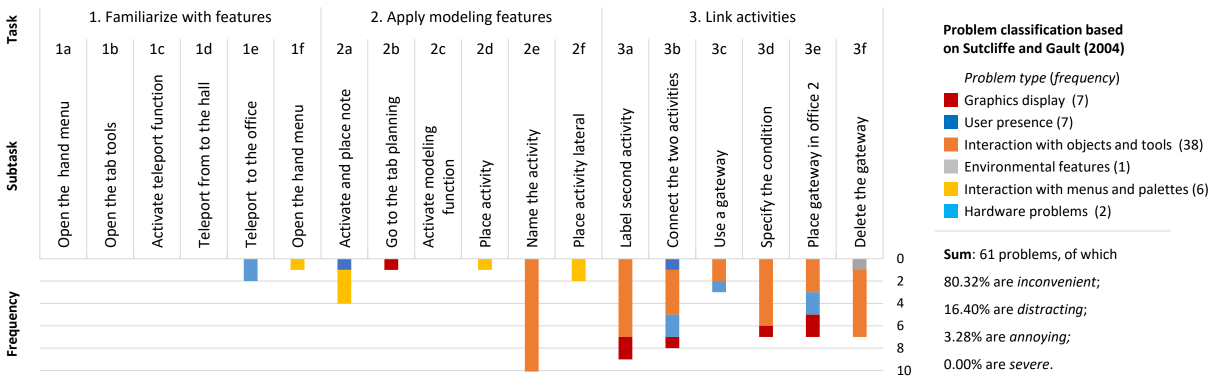

Figure 12. Results of the cognitive walkthrough (Pöhler et al. 2021)

Most of the problems were found to be rather inconvenient but did not disrupt the process any further. A major source of errors was the interaction with the elements (63%), with arrow docking to process elements and text input using the VR keyboard particularly causing problems. Based on the insights gained, the docking was adapted by allowing a partially automated arrow docking to process elements, and the VR users' text input and the teleport were refined regarding accuracy (Pöhler et al. 2021).

Evaluation cycle 3: Usefulness

According to FEDS (Venable et al. 2016), testing an artifact's usefulness is advisable in real-work situations and environments. Therefore, the VR-BPM system was evaluated regarding its usefulness in different operational BPM phases (elicitation, analysis, redesign) in field studies in three SMEs from different industries (food, steel, and glass trade) in Contribution E. Usefulness was given if the artifact contributed to overcoming challenges in current BPM activities. A separate workshop was designed for each process elicitation, analysis, and redesign so that feedback of several field studies was received. The field studies were each designed so that employees from operational processes and management were involved in design activities in a multi-user mode. The workshops were evaluated qualitatively through individual interviews, focus group discussions, and shadowing. In the run-up to the initial field studies, SME staff were also tasked with designing the work environment using the layout tool, scans, and CAD data. The insights gained from the evaluation workshops were subsequently classified using a qualitative content analysis according to Mayring (2004) with regard to overcoming consistency, automated fiction, project-management and motivation problem.

Users found creating process models in their familiar working environments extremely helpful to overcome the **consistency problem**. The replicas were deemed realistic since users had no difficulty orienting themselves and placing process elements in the right location. The connection between the environment and the process executed within it increased users' understanding and interest. In initial workshops, the users had previously only worked with 2D processes; therefore, they could compare the environments. The small number of different modeling elements was also deemed beneficial, as it prevented users from experiencing information overload (Pöhler et al. 2021). Moreover, workshop participants indicated that the VR-BPM system could mitigate the **automated-fiction problem**. Planned target processes could be directly experienced by interacting with process elements in the work environment. For example, it was noted that integrating a tablet into one SME's workflow would not make sense because it would be too unwieldy to interact with. With a pure 2D process design, "this would probably not have been noticed at all." Through increased contextualization and interaction, VR offers the possibility of minimizing process-planning errors, which can cause lower quality costs in the real process (Pöhler and Teuteberg 2022). The **project-management problem** was only partially resolved by VR specifics yet was reduced by the multi-user access and the compressed and unspecified modeling convention. Multi-user editing gave participants confidence in the creation process by allowing them to consult and exchange ideas. Additionally, lower-ranked employees, in particular, indicated that they naturally took the lead in VR and also analyzed honestly and critically even though their supervisors were present. Thus, VR can facilitate overcoming organizational barriers since a certain separation from reality, structures, and roles occurs (Pöhler et al. 2021). Furthermore, it was confirmed in the workshops that the modeling convention was designed so that an understanding of process elements and their creation was generated across disciplines. Users consistently confirmed that VR increased their engagement in BPM activities compared to 2D representations, thus, helping overcome the **motivation problem**. Characteristic-related advantages, such as immersion, realism, and interactivity, would guarantee a high experiential content of processes and motivate participation. In addition, it was positively emphasized that VR encourages "being allowed to make mistakes" without impacting real production processes. Consequently, VR invites people to try things and think more creatively "than if you simply play it out on paper" (Pöhler et al. 2021, p. 12).

However, in addition to these positive aspects, VR-BPM system weaknesses were also mentioned. For example, its use may be too time-consuming for short processes that require quick outlining. Further, some workshop participants felt there was a lack of overview; a bird's-eye view of the processes was desired. The strict separation of modeling and layout mode for workstation design was also criticized. Instead, participants demanded a barrier-free transition enabling interaction with environment elements directly during process design (Pöhler et al. 2021).

3.2.4 Effectiveness and Efficiency of the VR-BPM System

Field-study feedback showed that VR systems for process design offer added value, especially when combined with interactive possibilities for workplace design. This combination allows users to directly experience the planned process changes by interacting with process elements, such as tools, vehicles, or simulated information systems. Such a system for combined workplace and process design was investigated in Contributions F and G regarding its long-term economic impact on organizations. With the help of a CBA, according to Sassone and Schaffer (1978), it was possible to determine the circumstances under which an investment in the VR system is profitable.

An eight-step procedure model was developed to determine costs and benefits and their quantification (see Figure 13). The development of the model was based on a DSR cycle according to Peffers (2007), leading to a problem-based procedure for better estimation of quantified costs and benefits in IS investments. On the problem space, the estimation of costs and benefits is still a major issue in IS investment considerations (Murphy and Simon 2002; Oesterreich and Teuteberg 2017). In the solution space, Goodhue and Thompson's (1995) Task-Technology-Fit (TTF) approach plays a central role, as it was integrated into existing cost and benefit overviews of IS according to Irani and Love (2000) and Irani (2002). The aim was to determine the expected VR system's utilization *ex-ante* by integrating the TTF theory. Since the expected utilization contributes to almost all cost-benefit categories, a higher quantification accuracy is achieved (Pöhler et al. 2023).

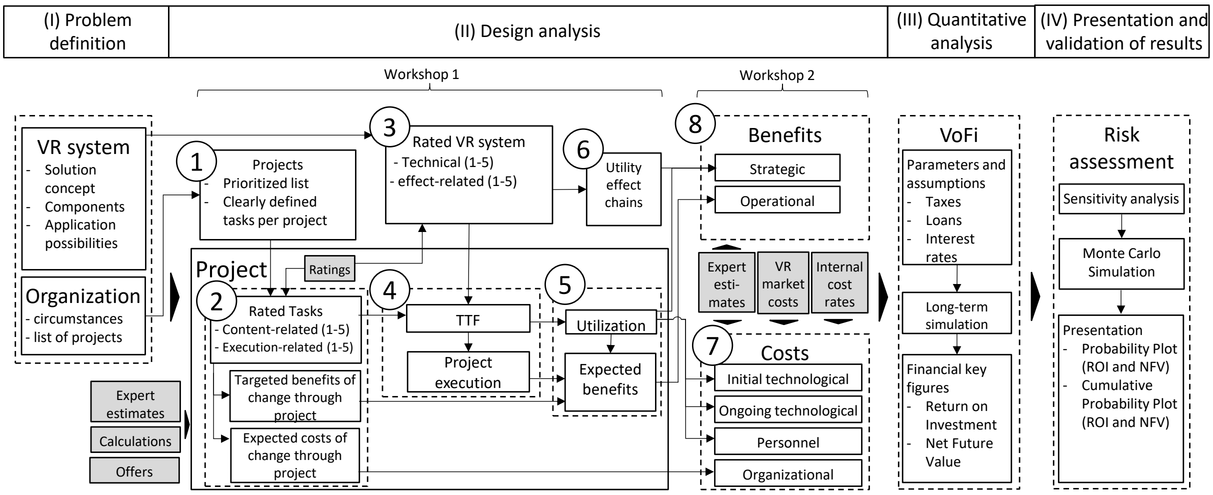

Figure 13. Suitability and utilization-based CBA (Pöhler and Teuteberg 2023)

By applying the eight-step model, VR-system costs and the benefits for combined workplace and process design could be determined and quantified in a suitability- and utilization-oriented way. Regarding costs, reference was made to accepted cost overviews according to Irani and Love (2000) and Irani (2002). In addition, cost types were determined for which system utilization plays a role in quantification. The quantification was conducted in workshops with the help of expert knowledge and empirical values.

However, greater difficulty with CBA in IS lies in quantifying benefits (Oesterreich and Teuteberg 2018). The long-term strategic benefits are particularly difficult to quantify. Frequently, there are intangible benefits, namely, benefits that cannot be quantified and are not useful for economic considerations (Murphy and Simon 2002). In this case, using utility-effect chains, according to Schumann and Linß (1993), enables intangible benefits' transformation into tangible benefits, which are quantifiable and usable for a CBA (Oesterreich and Teuteberg 2018). By applying utility-effect chains, an overall view of a VR system's benefits for workplace and process design could be determined. Finally, an overall utility-effect chain resulting in cost savings within an organization was obtained (Figure 14). This result shows that using the VR system ultimately leads to savings within an organization in health, quality, productivity, and travelling (Pöhler and Teuteberg 2022).

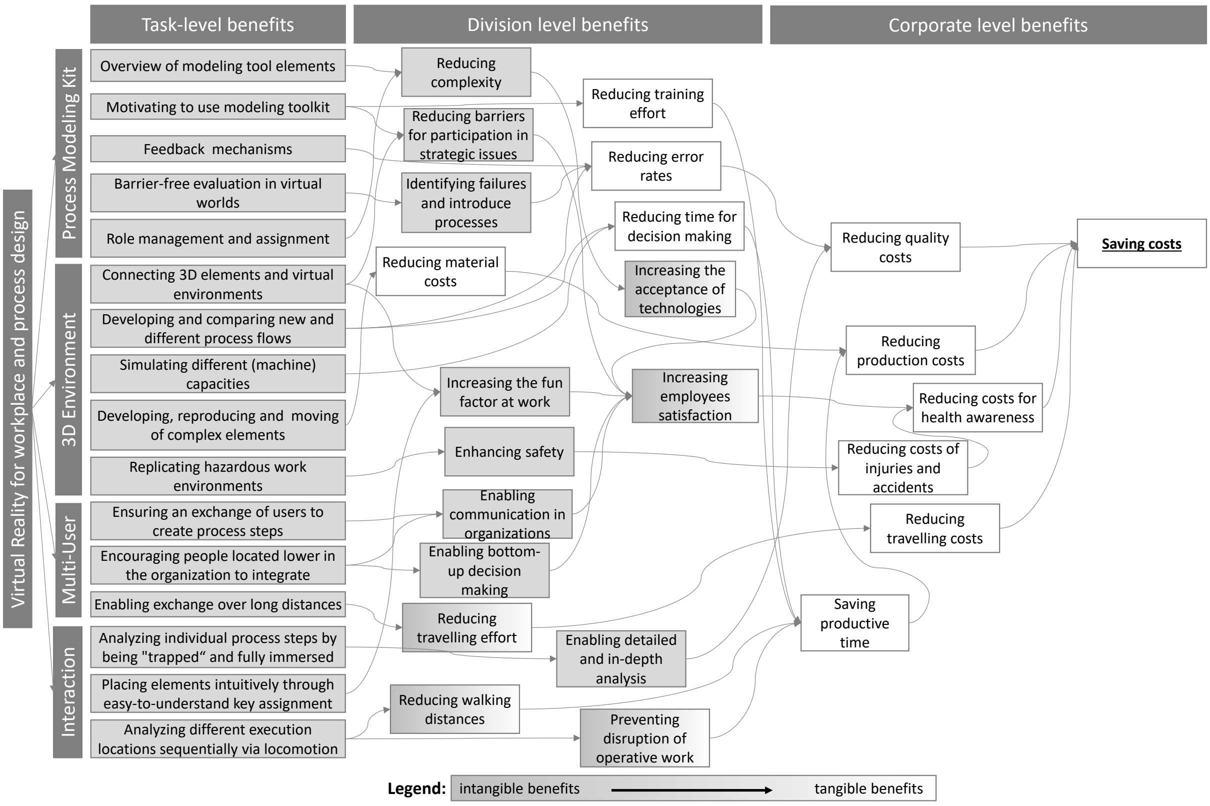

Figure 14. VR benefits for workplace and process design based on Pöhler and Teuteberg (2022)

Based on the cost-benefit overviews, a concrete CBA could be conducted in a case study with one of the three application SMEs from the field studies in Contribution H. Quantification was based on forecasting future utilization, internal cost rates, and expert management estimates. It emerged that VR's use for workplace and process design delivers added monetarily value from a long-term perspective of 10 years. Figure 15 shows a risk assessment of the investment generated by the Monte Carlo simulation with 1,000 different cases. Accordingly, the VR implementation delivers, with a 90% probability, a return on investment of at least 451,226 € and a net future value of 57.1% (in one of the considered SMEs from the VR-BPM systems field studies).

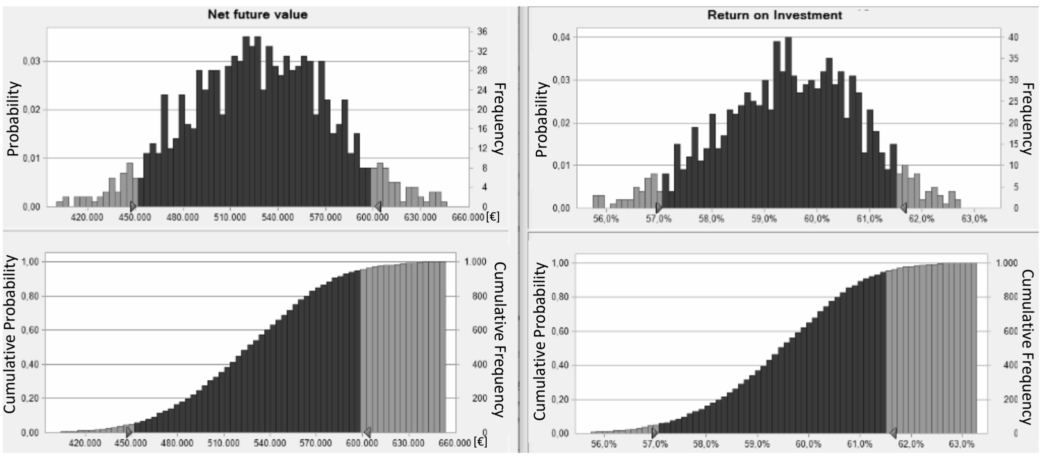

Figure 15. Monte-Carlo simulation of VR-BPM investment (Pöhler and Teuteberg 2023)

Based on the simulation data, five key factors were identified that determine investment in VR's profitability for collaborative and contextualized workplace and process design in organizations. In summary, organizations should invest that (1) have many strategic workplace and process-design projects, (2) require creative, collaborative, and detailed process planning, (3) have already achieved a high level of technology readiness, (4) are geographically dispersed, and (5) have a large amount of CAD data available for VR integration (Pöhler and Teuteberg 2023).

3.3 Implementing VR in Organizations

Achieving ambidexterity is increasingly required for organizations (Schneeberger and Habegger 2020). To meet this trend, organizations are required to combine exploration – incorporating new knowledge and technologies – with exploitation, namely, relying on the proven and established (O'Reilly and Tushman 2008). Regarding disruptive technologies such as VR, organizations lack specific tools and methods that promote achieving organizational ambidexterity (Berg and Vance 2017; Jabil 2018). VR – like AR – has specifics that make a standardized implementation, as with pure software tools, such as customer relationship management, less promising (Jabil 2018).

Referring to RQ3, a tool and an associated method were developed for this purpose in Contribution H to facilitate integrating the VR-BPM system into existing organizational structures in a beneficial way. To this end, findings and preliminary work of the canvas methodology according to Osterwalder and Pigneur (2010) were adapted to VR specifics. The canvas methodology has already been successfully specified for other IS topics, such as artificial intelligence and big data (cf.Kerzel 2021; Kaufmann 2019), which is why a transfer to XR seems promising. Applying a single build-evaluate cycle according to Peffers et al. (2007) resulted in the XR-Canvas, which can be used for implementing AR and VR due to their related characteristics.

Based on a systematic literature review according to vom Brocke et al. (2009), action fields and their interrelationships were first identified. Eleven action fields were selected to enable a holistic implementation view from the perspectives of technology, organization, environment, and individuals according to the TOEI framework (Depietro et al. 1990). Specific questions aimed at exploration and exploitation were subsequently integrated into the respective fields, which can be answered collaboratively within workshops (cf. Figure 16). The canvas is designed so that an increasingly higher level of detail can be achieved in several iterations.

Compared to other technology-specific canvases, such as those by Kerzel (2021) or Kaufmann (2019), it is particularly noticeable that the action fields of law and health are covered by a high number of questions. Legal aspects are relevant because XR technologies use tracking systems that can generate sensitive individual data like body movements

(Schuir et al. 2022). On the other hand, environments can also be recorded and, for example, highly confidential company data can be filmed. The health aspects to be considered relate to both mental (vertigo, dizziness) and possible physical (neck and shoulder pain) effects (Saredakis et al. 2020). Overall, the canvas reflects that XR technologies have a disruptive character and their implementation is accompanied by consideration of multiple sensitive issues (Pöhler et al. 2023).

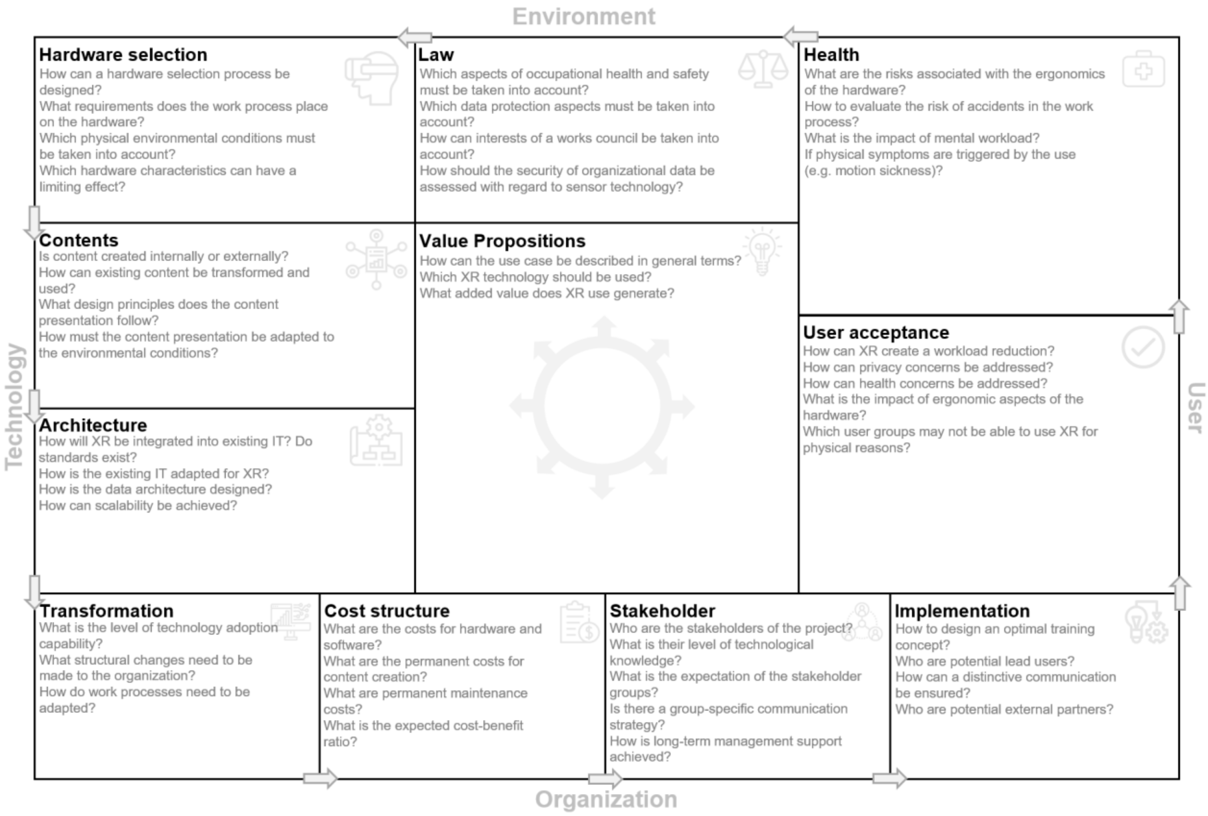

Figure 16. The XR-Canvas based on Pöhler et al. (2023)

After the canvas was developed, it was presented to four experts from practice and science. They could walk through the different fields based on an application example and evaluate the XR-Canvas regarding the criteria of completeness, usability, and usefulness, as Sonnenberg and vom Brocke (2012) recommend. Consequently, five recommended actions for XR-Canvas's application and use were derived. In summary, integrating XR-specific implementation issues into a canvas was found useful (Pöhler et al. 2023). However, XR should be applied so that concrete use cases are available first (rather than conducting technology-driven workshops). With the XR-Canvas, external consulting costs can be saved, and implementation errors can be prevented early. In addition, using the XR-Canvas promotes organizational ambidexterity, allowing technological progress (exploration) while maintaining productivity and profitability (exploitation).

4 Discussion

4.1 Implications for Research

This cumulative dissertation aims to examine VR's potential, design knowledge, and implementation to overcome existing challenges of BPM in organizations. Consequently, eight individual contributions provide a holistic view of VR and BPM's symbiosis from a socio-technical perspective. Valuable research implications are gained, which this section outlines.

First, publications A and B provide descriptive knowledge about VR's general potential for BPM activities and, thus, answer RQ1. Publication A provides a structured overview of 13 characteristic-related and 10 effect-related advantages of VR's use by referring to working-context literature. Listing the overarching and differentiated advantages of VR in the work context contributes to a broader understanding of VR's potential use. DSR researchers can benefit from this overview by using it for feasibility studies at the beginning of their projects to test for suitability theoretically to avoid misdirected efforts (Sonnenberg and vom Brocke 2012). In addition, Publication B offers behavioral insights regarding VR's use for BPM activities via a comparative study. The weak-point analysis of an example process in the study indicated that VR is particularly advantageous where detailed analyses are necessary (Pöhler and Teuteberg 2021). Since VR users cannot quickly switch between process elements, as with 2D BPM tools, individual elements are examined more than in classic 2D tools. Moreover, according to the examined constructs, hedonistic and motivational aspects are more pronounced in VR, which can serve as an entry point for organization non-experts to engage in BPM activities. Future work can build on this knowledge by investigating VR's potential in, for example, creativity-heavy research fields, especially in contexts rich in detail and complexity in 2D. Likewise, VR artifacts can be generated with DSR activities that build on VR's hedonistic and collaborative potential to overcome motivational barriers in organizations.

RQ2 is answered in the Contributions C–G. Contributions C–E contribute to the design knowledge of VR and BPM systems. The conjoint analysis of 225 participants in Contribution C leads to a validated and deeper understanding of user preferences and configuration of VR systems regarding hardware and interaction. The results showed that users prefer a barrier-free user experience with high screen quality and multiple interaction possibilities. Data protection is less of a focus for users, even though they demand a customizable privacy policy. From a research perspective, the knowledge acquired from the preference analysis is significant for designing interactive VR systems, developed in further DSR projects. Moreover, differentiated user preferences also contribute to more in-depth VR technology acceptance research than, for example, Davis's (1989) technology-acceptance model allows. Another key result this dissertation offers is the design knowledge generated in Contributions D and E. As recommended by vom Brocke et al. (2020), drawing on existing design knowledge from previous DSR projects such as Vogel et al. (2021) counteracts a monolithic structure of DSR. The design principles generated can be classified as nascent design theory, according to Gregor and Hevner (2013). Thus, the principles provide not only design knowledge for a specific instantiation but also contain higher-level guidance for VR systems' general design. The generated prescriptive knowledge can be used in creatively and efficiently designing new VR systems in related application areas, such as training or factory planning in VR, due to its novelty (e.g., use of LiDAR scans for efficient environment design). Moreover, this dissertation contributes substantively to using kernel theories in DSR projects from two perspectives. First, Contribution E represents the first highly ranked DSR contribution at IS conferences that uses kernel theory to transform and operationalize meta-requirements into design principles (Möller et al. 2022). Second, the transformation occurs using Kahn's (1990) engagement theory, which has received much attention in employment psychology and whose operationalization in IS was systematically performed in Contribution E for the first time. This can serve future DSR projects, especially for artifacts to overcome motivational barriers in organizational settings.

Furthermore, instantiating the design principles with a VR-BPM artifact provides a valuable contribution to BPM research. By incorporating spatial and motivational VR characteristics, overcoming current BPM challenges could be demonstrated in several field studies. Thus, the artifact meets vom Brocke et al.'s (2021) demand for more contextualization in BPM. Furthermore, the artifact offers possible application in all operational BPM stages (cf. Dumas et al. 2018). For digitization efforts in organizations especially, the VR artifact offers advantages for realistic analysis and target processes simulation by allowing assessments of socio-technical process changes at the competency level. Therefore, this dissertation's results demonstrate that VR can advance the necessary symbiosis of digital innovation and BPM demanded by Grisold et al. (2021). For the BPM community, the findings are significant, as they provide design knowledge for contextualizing, collaborating, and integrating valuable tacit knowledge in BPM tools to overcome current challenges.

The F and G Contributions further answer RQ2 by considering VR's long-term economic impact on integrated workplace and process design. The results show that a high motivation to use VR for BPM activities, caused by its collaborative and hedonistic character, can generate long-term savings in production, travel, absence, and quality costs. From a methodological viewpoint, Contribution G especially provides a valuable extension of the knowledge base in the quantitative *ex-ante* CBA of IS. By incorporating Goodhue and Thompson's (1995) TTF into CBA, researchers can achieve increased validity in quantifying IS costs and benefits to be implemented in organizations. By developing this suitability- and utilization-based approach, the call for better quantifiability of intangible IS benefits can be met (Murphy and Simon 2002, Oesterreich and Teuteberg 2018).

Based on the findings from Contributions F and G, and by developing and evaluating the XR-Canvas generated in Contribution H, RQ3 could be answered, aiming at identifying and meeting the challenges of XR implementation holistically in organizations. The XR-Canvas was designed to be applied equally to the organizational implementation of VR and AR technologies to achieve broader utility and stronger generalizability. Researchers can primarily use the design knowledge generated by the canvas, including technology-specific characteristics, for achieving ambidexterity in organizations. Thus, the XR-Canvas closes the research gap that existed from the lack of efficient instruments for holistically implementing XR technologies (cf. Jabil 2018). Simultaneously, the canvas promotes disseminating generated IT artifacts into practice, which is important from the perspective of the practice-oriented research discipline IS (Österle et al. 2011).

In total, this dissertation's findings contribute manifold insights to the IS research knowledge base. DSR researchers in highly immersive interaction systems and the BPM community can particularly benefit. In addition, related disciplines (e.g., work and organizational sciences, business administration, HCI) can use the findings regarding the potential, design, and implementation of VR systems in work environments for more in-depth research.

4.2 Implications for Practice

The IS discipline aims to promote disseminating gained knowledge into practice to provide decision support and recommendations for action to organizations, IT developers, service providers, and political decision-makers (Hevner et al. 2010). This dissertation primarily addresses the practical need for better operationalization of BPM activities as organizations demonstrate a discrepancy between the BPM’s importance and its realization (BearingPoint 2021). In addition, this cumulative dissertation provides valuable insights from which various stakeholders from the VR and BPM landscape can benefit.

Organizations can especially benefit from the findings if they find themselves in a period of digital transformation or (re-)structuring an organizationally embedded process management. SMEs may strongly benefit in this regard, as they typically – as in the underlying research project – do not have independent business units for BPM (Liao and Barnes 2015). Instead of relying on conventional methods for documenting tacit and explicit knowledge, such as document reviews, interviews, or analog workshops (cf. Fleischmann et al. 2012), VR can increase employee motivation to participate in BPM activities (Pöhler and Teuteberg 2021). VR can be used in all the BPM cycle stages to collect, model, analyze, and test processes. Using VR in all phases is not mandatory but can be selected as a supplement to the conventional methods mentioned, especially where detailed analyses must be conducted collaboratively (Pöhler et al. 2021). If process modeling is accompanied by redesigning work environments, the VR-BPM artifact described in Contribution E is especially efficient. Geographically distributed companies can also benefit from VR's collaborative nature in the course of increasing globalization and rising price pressure by saving travel costs and efforts (Pöhler and Teuteberg 2022). Additionally, organizations can conduct the utilization-based CBA presented in papers F and G to assess the overall long-term consequences of an investment in disruptive VR technology and support decision-making. Technology assessments are supported by providing a transparent costs and benefits overview, avoiding misinvestments. The XR Canvas from article H can be applied to enable organizations to manage VR's implementation from a TOEI perspective. This tool especially enables VR-inexperienced organizations to realize exploration and exploitation in a sound balance in innovation management (Pöhler et al. 2023).

Process-management consultancies can also expand their service portfolios by incorporating VR as a motivational and inspirational technology. Due to VR's specifics, it is advisable to provide support during early application phases so that consulting firms can profitably contribute their high methodological expertise (Pöhler et al. 2023; Berg and Vance 2017). The practice-relevant XR-Canvas can also serve consulting companies in structuring and conducting implementation workshops for AR or VR use cases.

Finally, software and hardware providers from the VR ecosystem can benefit from the findings of Contributions C–E. Firstly, the identified user preferences provide a transparent overview of the relative importance of individual attributes, such as display quality and interaction possibilities. Moreover, insights can motivate software vendors to address the need for customizable and transparent privacy policies (De Guzman et al. 2019) to avoid privacy concerns among cautious users. Furthermore, the design knowledge from Contributions D and E can aid software vendors in developing efficient interactive VR systems. In this context, the findings on efficient environment design using LiDAR scanners, which are integrated into modern smartphones, are particularly valuable since environment creation in VR generates a high time and cost overhead (Hilfert and König 2016).

Summarizing, this cumulative dissertation offers valuable insights for a broad class of practitioners. Especially organizations in search of assistance in operational process design and integrating VR into new or existing structures can profit strongly. Likewise, the findings can benefit consultants and software and hardware providers for highly immersive systems.

4.3 Limitations and Future Research

Due to the double-blind peer review process, the scientific quality, relevance, and rigor, this dissertation's eight contributions were examined and confirmed. Nevertheless, as with any research project, this dissertation's limits are listed below with identified future research.

Despite its structured approach, the literature review, according to vom Brocke et al. (2009), conducted in all contributions cannot guarantee the retrieval of all relevant literature. The limitation to selected databases, such as Scopus, Google Scholar, or EbscoHost, and the pre-sorting only by title and abstract are, consequently, resulting error sources. However, as the research of each contribution was specifically aligned to the respective research questions and interdisciplinary databases were also included, this dissertation should have included the largest part of the relevant literature.

Furthermore, this dissertation has a limited variety of application domains in which the generated artifacts were tested. For the VR-BPM artifact, the various field studies were conducted in three different companies from different industries. However, in each case, the companies are SMEs that share common specifics due to limited budgets and human resources (Dallas and Wynn 2014). Therefore, a VR trial in BPM activities of corporate groups and larger organizations could provide insights into future research on whether its use promotes similar benefits regardless of size, such as higher employee motivation and overcoming organizational role barriers (cf. Pöhler et al. 2021). In addition, the XR-Canvas was not tested in an organizational environment; its general completeness and usability were only demonstrated through expert interviews. Consequently, applying the XR-Canvas in field studies in compliance with the three realities, according to Sonnenberg and vom Brocke (2012), would provide valid insights into its usefulness and efficiency as a workshop instrument.

In addition, the quantitative studies conducted in Contributions B, C, and G contain limitations. Contribution B's comparative study was conducted with a small number of 28 participants. In addition, the participants could be classified as digital natives due to the predominant age between 20–30 with a high proportion of academics, leading to biases of the present reality in organizations, which is a general problem in IS research (Friedman and Nissenbaum 1996). A comparative study with a larger and more heterogeneous participant pool could provide further insight. Conjoint analyses, as conducted in Contribution C, have general limitations. These include the scenario choices and selecting attributes and their values. For example, even the order of the scenarios listed can change the results (Chrzan 1994). Therefore, triangulating the findings could provide less-biased insights (Schuir et al. 2022). Moreover, due to a limited database, the CBA from Contribution G results partly on estimates of quantified costs and benefits and was conducted only in one application organization. In addition, there are general inaccuracies in CBAs, such as overlapping effects (Irani et al. 2006), unclear system boundaries (Oesterreich and Teuteberg 2018), or simplified technology adoption processes in organizations (Depietro et al. 1990). An expansion of the data base and applying the specifics of further application organizations could provide additional insights into the general conditions under which an investment in VR for BPM is profitable (Pöhler and Teuteberg 2022).

Finally, within a time-limited research project – such as the underlying SoDigital project – it is not possible to validly determine long-term effects. A retrospective analysis is required to validate the results from the simulated *ex-ante* utility–effect chains, which is only possible 5–10 years after the project. Among other things, the German research landscape and the political framework lack the possibilities and instruments to conduct long-term success controls of projects in a structured and efficient way.

5 Conclusion

This cumulative dissertation presents results from eight individual contributions (A–H) in an overall context. The goal was to examine the potential, design, implementation, and long-term use of VR technology for managing business processes in organizations through a sociotechnical and economic lens. Consequently, valuable findings could be derived for research and practice.

A combined feasibility study (Contributions A and B) demonstrated VR's general suitability for overcoming current motivational and contextual BPM challenges. The subsequently developed VR artifact for business-process design and analysis was based on a broad knowledge base, including user preferences for interaction and VR use (Contribution C). The design knowledge generated in Contributions D and E and its instantiation forms the dissertation's core. Scientists can build on the generated design principles when designing highly immersive IS artifacts. Evaluations of the instantiated VR artifact in real-world work environments revealed that VR could help overcome BPM motivational and contextual challenges. Practitioners can benefit from this knowledge by integrating VR formats in workshops to increase employee engagement in collaborative work on strategic topics. In addition, by determining and simulating the long-term economic consequences of using VR for workplace and process design, how VR can lead to cost savings within an organization (Contributions F and G) became apparent. The developed model for utilization-based *ex-ante* CBA can serve scientists in IS in economically evaluating generated artifacts. Furthermore, the XR-Canvas developed in Contribution H contributes to the holistic planning of implementing highly immersive and disruptive technologies, such as AR and VR, in organizations. By using the planning tool, organizational ambidexterity can be strengthened by implementing novel XR technology under consideration of organizational and economic conditions.

In summary, this dissertation's findings contribute to a better understanding of sociotechnical interrelationships between individuals and highly immersive technologies in the organizational process and work environment. Consequently, the technical, social and economic findings promote the dissemination of VR for manifold practical use cases.

References

Aalst, W. M. P. van der (2013). “Business Process Management: A Comprehensive Survey,” ISRN Software Engineering (2013), pp. 1–37.

Abdul, B. M., Corradini, F., Re, B., Rossi, L., and Tiezzi, F. (2019). “UBBA: Unity Based BPMN Animator,” in International Conference on Advanced Information Systems Engineering, pp. 1–9.

Allen, J., Davis, N. (2019). "Measuring operational resilience using the CERT® resilience management model," Software Engineering Institute, CERT Program, Carnegie Mellon University.

Amrhein, V., Greenland, S., and McShane, B. (2019). “Scientists Rise up against Statistical Significance, ” Nature (567), pp. 305-307.

Andres, M., Ziekow, H., Zimmermann, K. and Campinar, S. (2018). Visualizing Business Process Models on Virtual Reality Screens, Mensch und Computer.

Anselstetter, R. (1984). “Betriebswirtschaftliche Nutzeffekte Der Datenverarbeitung,” Berlin Springer.

Anthes, C., García-Hernández, R. J., Wiedemann, M., and Kranzlmüller, D. (2016). “State of the Art of Virtual Reality Technology,” in Proceeding of the IEEE Aerospace Conference, pp. 1–19.

Aysolmaz, B., Brown, R., Bruza, P., and Reijers, H. A. (2016). “A 3D Visualization Approach for Process Training in Office Environments,” Lecture Notes in Computer Science (10033), pp. 418–436.

Badakhshan, P., Conboy, K., Grisold, T., and vom Brocke, J. (2019). "Agile business process management: A systematic literature review and an integrated framework," Business Process Management Journal (26:6), pp. 1505-1523.

Baethge, A., Rigotti, T., and Roe, R. A. (2015). “Just More of the Same, or Different? An Integrative Theoretical Framework for the Study of Cumulative Interruptions at Work,” European Journal of Work and Organizational Psychology (24:2), pp. 308–323.

Baskerville, R. L., and Myers, M. D. (2002). “Information Systems as a Reference Discipline,” MIS Quarterly (26:1), pp. 1–14.

BearingPoint. (2021). “Prozesse Effizient Managen Und Nachhaltig Verbessern - Process Management & Analytics Studie.” (https://www.bearingpoint.com/de-de/insights-events/insights/process-management-analytics-studie/, accessed April 4, 2023).

Becker, J., Rosemann, M., and von Uthmann, C. (2000). “Guidelines of Business Process Modeling,” in Business Process Management, Berlin, Heidelberg: Springer, pp. 30–49.

Berg, L. P., and Vance, J. M. (2017). “Industry Use of Virtual Reality in Product Design and Manufacturing: A Survey,” Virtual Reality (21:1), pp. 1–17.

Bider, I., and Perjons, E. (2015). “Design Science in Action: Developing a Modeling Technique for Eliciting Requirements on Business Process Management (BPM) Tools,” Software and Systems Modeling (14:3), pp. 1159–1188.

Bögel, S., Stieglitz, S., & Meske, C. (2014). "A role model-based approach for modelling collaborative processes," Business Process Management Journal (20:4), pp. 598-614.

vom Brocke, J., Baier, M.-S., Schmiedel, T., Stelzl, K., Röglinger, M., and Wehking, C. (2021). “Context-Aware Business Process Management,” Business & Information Systems Engineering (62), pp. 1–18.

vom Brocke, J., Hevner, A., and Maedche, A. (2020). “Introduction to Design Science Research,” Design Science Research. Cases, Springer, pp. 1–13.

vom Brocke, J., and Lippe, S. (2010). "Taking a Project Management Perspective on Design Science Research," in Proceedings of the 5th International DESRIST Conference, St. Gallen, Switzerland, pp. 31–44.
vom Brocke, J. , Simons, A., Niehaves, Bjoern, Niehaves, Bjorn, Reimer, K., Plattfaut, R., and Cleven, A. (2009). "Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process," in Proceedings of the 17th European Conference on Informations Systems (ECIS), pp. 2206–2217.
vom Brocke, J., Winter, R., Hevner, A., and Maedche, A. (2020). "Special Issue Editorial – Accumulation and Evolution of Design Knowledge in Design Science Research: A Journey through Time and Space," Journal of the Association for Information Systems (21:3), pp. 520–544.
Brown, R., and Cliquet, F. (2008). "Communication of Business Process Models via Virtual Environment Simulations," BPTrends (12:9), pp. 1–7.
Brown, R., Recker, J., and West, S. (2011). "Using Virtual Worlds for Collaborative Business Process Modeling," Business Process Management Journal (17:3), pp. 546–564.
Brown, R., Rinderle-Ma, S., Kriglstein, S., and Kabicher-Fuchs, S. (2014). "Augmenting and Assisting Model Elicitation Tasks with 3D Virtual World Context Metadata," Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) (8841), pp. 39–56.
Burton-Jones, A., and Lee, A. S. (2017). "Thinking about Measures and Measurement in Positivist Research: A Proposal for Refocusing on Fundamentals," Information Systems Research (28:3), pp. 451–467.
Chrzan, K. (1994). "Three Kinds of Order Effects in Choice-Based Conjoint Analysis," Marketing Letters (5), pp. 165–172.
Cohen, J. (2013). Statistical Power Analysis for the Behavioral Sciences, Academic press.
Creswell, J. W., and Creswell, J. D. (2017). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Sage publications.
Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., and Hanson, W. E. (2003). "Advanced Mixed Methods Research Designs," Handbook of Mixed Methods in Social and Behavioral Research (209:240), pp. 209–240.
Dallas, I., and Wynn, M. T. (2014). "Business Process Management in Small Business: A Case Study," Information Systems for Small and Medium-Sized Enterprises: State of Art of IS Research in SMEs, pp. 25–46.
Davis, F. D. (1989). "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," MIS Quarterly (13:3), pp. 319–340.
Depietro, R., Wiarda, E., and Fleischer, M. (1990). "The Context for Change: Organization, Technology and Environment," The Processes of Technological Innovation , pp. 151–175.
Dumas, M., La Rosa, M., Mendling, J., and Reijers, H. A. (2013). "Fundamentals of Business Process Management," Springer.
Dumas, M., La Rosa, M., Mendling, J., Reijers, H. A., Dumas, M., La Rosa, M., Mendling, J., and Reijers, H. A. (2018). "Introduction to Business Process Management," Fundamentals of Business Process Management, Springer, pp. 1–33.
Elstermann, M., & Piller, C. (2022). "A Comparative Study of Simulation Tools for Business Processes," in International Conference on Subject-Oriented Business Process Management, pp. 61-78, Cham: Springer Nature Switzerland.
Erol, S., Granitzer, M., Happ, S., Jantunen, S., Jennings, B., Johannesson, P., Koschmider, A., Nurcan, S., Rossi, D., and Schmidt, R. (2010). "Combining BPM and Social Software: Contradiction or Chance?," Journal of Software Maintenance and Evolution: Research

and Practice (22:6-7), pp. 449–476.
Fleischmann, A., Schmidt, W., Stary, C., Obermeier, S., and Börger, E. (2012). “Subject-Oriented Business Process Management,” Springer Nature.
Forster, S., Pinggera, J., and Weber, B. (2013). “Toward an Understanding of the Collaborative Process of Process Modeling,” in CAiSE Forum (Vol. 998), pp. 98–105.
Friedman, B., and Nissenbaum, H. (1996). “Bias in Computer Systems,” ACM Transactions on Information Systems (14:3), pp. 330–347.
Fromm, J., Stieglitz, S., and Mirbabaie, M. (2020). “The Effects of Virtual Reality Affordances and Constraints on Negative Group Effects during Brainstorming Sessions,” in Proceeding of the Fifteenth International Conference on Wirtschaftsinformatik, pp. 1172–1187.
Frommel, J., Sonntag, S., and Weber, M. (2017). “Effects of Controller-Based Locomotion on Player Experience in a Virtual Reality Exploration Game,” in Proceedings of the 12th International Conference on the Foundations of Digital Games, pp. 1–6.
Gibson, C. B., and Birkinshaw, J. (2004). “The Antecedents, Consequences, and Mediating Role of Organizational Ambidexterity,” Academy of Management Journal (47:2), pp. 209–226.
De Giorgio, A., Romero, M., Onori, M., and Wang, L. (2017). “Human-Machine Collaboration in Virtual Reality for Adaptive Production Engineering,” Procedia Manufacturing (11), pp. 1279–1287.
Gläser, J., and Laudel, G. (2010). Experteninterviews Und Qualitative Inhaltsanalyse (2. Edition), Wiesbaden.
Goodhue, D. L., and Thompson, R. L. (1995). “Task-Technology Fit and Individual Performance,” MIS Quarterly (19:2), pp. 213–233.
Green, P. E., and Srinivasan, V. (1978). “Conjoint Analysis in Consumer Research: Issues and Outlook,” Journal of Consumer Research (5:2), pp. 103–123.
Gregor, S., Chandra Kruse, L., and Seidel, S. (2020). “Research Perspectives: The Anatomy of a Design Principle,” Journal of the Association for Information Systems (21:6), pp. 1622–1652.
Gregor, S., and Hevner, A. R. (2013). “Positioning and Presenting Design Science Research for Maximum Impact,” MIS Quarterly (37:2), pp. 337–355.
Guo, H., Brown, R., and Rasmussen, R. (2012). “Virtual Worlds as a Model-View Approach to the Communication of Business Processes Models,” in Proceedings of the CEUR Workshop (855), pp. 66–73.
De Guzman, J. A., Thilakarathna, K., and Seneviratne, A. (2019). “Security and Privacy Approaches in Mixed Reality: A Literature Survey,” ACM Computing Surveys (52:6), pp. 1–37.
Harman, J., Brown, R., Johnson, D., Rinderle-Ma, S., and Kannengiesser, U. (2016). “Augmenting Process Elicitation with Visual Priming: An Empirical Exploration of User Behaviour and Modelling Outcomes,” Information Systems (62), pp. 242–255.
Heinzl, A., Schoder, D., and Frank, U. (2008). “WI-Journalliste 2008 Sowie WI-Liste Der Konferenzen, Proceedings Und Lecture Notes 2008,” Wirtschaftsinformatik (50:2), pp. 155–163.
Herrmann, T. (2012). Kreatives Prozessdesign: Konzepte Und Methoden Zur Integration von Prozessorganisation, Technik Und Arbeitsgestaltung, Springer-Verlag.
Hevner, A., Chatterjee, S., and Iivari, J. (2010). “Twelve Theses on Design Science Research in Information Systems,” Design Research in Information Systems: Theory and Practice, Springer, pp. 43–62.
Hevner, A. R. (2007). “A Three Cycle View of Design Science Research,” Scandinavian

Journal of Information Systems (19:2), pp. 87–92.
Hevner, A. R., March, S. T., Park, J., and Ram, S. (2004). “Design Science in Information Systems Research,” MIS Quarterly (28:1), pp. 75–105.
Highsmith, J., and Cockburn, A. (2001). “Agile Software Development: The Business of Innovation,” Computer (34:9), pp. 120–127.
Hilfert, T., and König, M. (2016). “Low-Cost Virtual Reality Environment for Engineering and Construction,” Visualization in Engineering (4:1), pp. 1–18.
Hodgson, P., Lee, V. W. Y., Chan, J. C. S., Fong, A., Tang, C. S. Y., Chan, L., and Wong, C. (2019). “Immersive Virtual Reality (IVR) in Higher Education: Development and Implementation,” Augmented Reality and Virtual Reality: The Power of AR and VR for Business, Springer, pp. 161–173.
Hoppe, M., Knierim, P., Kosch, T., Funk, M., Futami, L., Schneegass, S., Henze, N., Schmidt, A., and Machulla, T. (2018). “VRHapticDrones: Providing Haptics in Virtual Reality through Quadcopters,” in Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia, pp. 7–18.
Irani, Z. (2002). “Information Systems Evaluation: Navigating through the Problem Domain,” Information & Management (40:1), pp. 11–24.
Irani, Z., Ghoneim, A., and Love, P. E. D. (2006). Evaluating Cost Taxonomies for Information Systems Management, (173), pp. 1103–1122.
Irani, Z., and Love, P. E. D. (2000). “The Propagation of Technology Management Taxonomies for Evaluating Investments in Information Systems,” Journal of Management Information Systems (17:3), pp. 161–177.
Jabil (2018). “The State of Augmented and Virtual Reality,” pp. 1–26. (https://www.jabil.com/dam/jcr:eacf5015-c278-4408-8eca-6c505e9ff4ff/ar-vr-trends-white-paper.pdf, accessed April 4, 2023).
Kahn, W. A. (1990). “Psychological Conditions of Personal Engagement and Disengagement At Work.,” Academy of Management Journal (33:4), pp. 692–724.
Kaplan, B., and Maxwell, J. A. (2005). “Qualitative Research Methods for Evaluating Computer Information Systems,” Evaluating the Organizational Impact of Healthcare Information Systems, Springer, pp. 30–55.
Kardas, G., Tezel, B. T., and Challenger, M. (2018). “Domain-Specific Modelling Language for Belief-Desire-Intention Software Agents,” IET Software (12:4), pp. 356–364.
Kathleen, N., Ross, B., and Kriglstein, S. (2014). “Storyboard Augmentation of Process Model Grammars for Stakeholder Communication,” in Proceedings of the 5th International Conference on Information Visualization Theory and Applications, pp. 114–121.
Kaufmann, M. (2019). “Big Data Management Canvas: A Reference Model for Value Creation from Data,” Big Data and Cognitive Computing (3:1), pp. 1–18.
Kerpedzhiev, G. D., König, U. M., Röglinger, M., and Rosemann, M. (2021). “An Exploration into Future Business Process Management Capabilities in View of Digitalization: Results from a Delphi Study,” Business and Information Systems Engineering (63:2), pp. 83–96.
Kerzel, U. (2021). “Enterprise AI Canvas Integrating Artificial Intelligence into Business,” Applied Artificial Intelligence (35:1), pp. 1–12.
Klein, H. K., and Myers, M. D. (1999). “A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems,” MIS Quarterly (23:1), pp. 67–93.
Kontio, J., Lehtola, L., and Bragge, J. (2004). “Using the Focus Group Method in Software Engineering: Obtaining Practitioner and User Experiences,” in Proceedings of the 2004 International Symposium on Empirical Software Engineering, pp. 271–280.

Lacko, J. (2020). “Health Safety Training for Industry in Virtual Reality,” in 2020 Cybernetics & Informatics (K&I), pp. 1–5.

Lee, Y., Kozar, K. A., and Larsen, K. R. T. (2003). “The Technology Acceptance Model: Past, Present, and Future,” Communications of the Association for Information Systems (12:1), p. 50.

Leyer, M., Aysolmaz, B., Brown, R., Türkay, S., and Reijers, H. A. (2021). “Process Training for Industrial Organisations Using 3D Environments: An Empirical Analysis,” Computers in Industry (124), p. 103346.

Leyer, M., Brown, R., Aysolmaz, B., Vanderfeesten, I., and Turetken, O. (2019). “3D Virtual World BPM Training Systems: Process Gateway Experimental Results,” in International Conference on Advanced Information Systems Engineering, pp. 415–429.

Liao, Y., and Barnes, J. (2015). “Knowledge Acquisition and Product Innovation Flexibility in SMEs,” Business Process Management Journal (21:6), pp. 1257–1278.

Mahatody, T., Sagar, M., & Kolski, C. (2010). "State of the art on the cognitive walkthrough method, its variants and evolutions," International Journal of Human–Computer Interaction (26:8), pp. 741-785.

Mayring, P. (2004). “Qualitative Content Analysis,” in A Companion to Qualitative Research , pp. 159–176.

Metzger, D., Niemöller, C., Wingert, B., Schultze, T., Bues, M., and Thomas, O. (2017). “How Machines Are Serviced - Design of a Virtual Reality-Based Training System for Technical Customer Services,” in Proceedings of the Twelth International Conference on Wirtschaftsinformatik (WI), pp. 604–618.

Möller, F., Schoormann, T., Strobel, G., and Hansen, M. R. P. (2022). “Unveiling the Cloak: Kernel Theory Use in Design Science Research,” in International Conference on Information Systems (ICIS), Copenhagen, Denmark.

Murphy, K. E., and Simon, S. J. (2002). “Intangible Benefits Valuation in ERP Projects,” Information Systems Journal (12:4), pp. 301–320.

Myers, M. D., and Newman, M. (2007). “The Qualitative Interview in IS Research: Examining the Craft,” Information and Organization (17:1), pp. 2–26.

Nolte, A., Brown, R., Anslow, C., Wiechers, M., Polyvyanyy, A., and Herrmann, T. (2016). “Collaborative Business Process Modeling in Multi-Surface Environments,” in Collaboration Meets Interactive Spaces, Springer, pp. 259–286.

Nunamaker, J. F., J., and Briggs, R. O. (2012). “Toward a Broader Vision for Information Systems,” ACM Transactions on Management Information Systems (2:4), pp. 1–12.

O’Reilly, C. A., and Tushman, M. L. (2008). “Ambidexterity as a Dynamic Capability: Resolving the Innovator’s Dilemma,” Research in Organizational Behavior (28), pp. 185–206.

Oberhauser, R., and Pogolski, C. (2019). “VR-EA: Virtual Reality Visualization of Enterprise Architecture Models with ArchiMate and BPMN,” in International Symposium on Business Modeling and Software Design, pp. 170–187.

Oberhauser, R., Pogolski, C., and Matic, A. (2018). “VR-BPMN: Visualizing BPMN Models in Virtual Reality,” in International Symposium on Business Modeling and Software Design, pp. 83–97.

Oesterreich, T. D., and Teuteberg, F. (2018). “Why One Big Picture Is Worth a Thousand Numbers: Measuring Intangible Benefits of Investments in Augmented Reality Based Assistive Technology Using Utility Effect Chains and System Dynamics,” Information Systems and E-Business Management (16:2), pp. 407–441.

Österle, H., Becker, J., Frank, U., Hess, T., Karagiannis, D., Krcmar, H., Loos, P., Mertens, P., Oberweis, A., and Sinz, E. J. (2011). "Memorandum on Design-Oriented Information Systems Research," European Journal of Information Systems (20:1), pp. 7–10.

Osterwalder, A., and Pigneur, Y. (2010). Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers, John Wiley & Sons.

Peffers, K., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. (2007). "A Design Science Research Methodology for Information Systems Research," Journal of Management Information Systems (24:3), pp. 45–77.

Pinggera, J., Soffer, P., Fahland, D., Weidlich, M., Zugal, S., Weber, B., Reijers, H. A., and Mendling, J. (2015). "Styles in Business Process Modeling: An Exploration and a Model," Software and Systems Modeling (14:3), pp. 1055–1080.

Pöhler, L., Belda, F., and Teuteberg, F. (2023). "Das Extended-Reality-Canvas–Wie können Unternehmen XR-Projekte erfolgreich implementieren?," HMD Praxis der Wirtschaftsinformatik, pp. 1–20.

Pöhler, L., Schuir, J., Lübbers, S., and Teuteberg, F. (2020). "Enabling Collaborative Business Process Elicitation in Virtual Environments," in Lecture Notes in Business Information Processing (Vol. 391), B. Shishkov (ed.), Springer, Cham, pp. 375–385.

Pöhler, L., Schuir, J., Meier, P., and Teuteberg, F. (2021). "Let's Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling," in Proceedings of the International Conference on Information Systems (ICIS), Austin, Texas.

Pöhler, L., and Teuteberg, F. (2021). "Closing Spatial Und Motivational Gaps: Virtual Reality in Business Process Improvement.," in Proceedings of the European Conference on Information Systems (ECIS), A Virtual AIS Conference.

Pöhler, L., and Teuteberg, F. (2022). "Unfolding Benefits of Virtual Reality for Workplace and Process Design Based on Utility Effect Chains," in Proceedings of the Pacific Asia Conference on Information Systems (PACIS), A Virtual AIS Conference.

Pöhler, L., and Teuteberg, F. (2023): "Utilization-based Cost-Benefit Analysis: A techno-economic Feasibility Study of Virtual Reality for Workplace and Process Design," Information Systems and e-Business Management (ISeB, under review (April 4, 2023)).

Poppe, E., Brown, R., Recker, J., and Johnson, D. (2013). "Improving Remote Collaborative Process Modelling Using Embodiment in 3D Virtual Environments," Conferences in Research and Practice in Information Technology Series (143:01), pp. 51–60.

Poppe, E., Brown, R., Recker, J., Johnson, D., and Vanderfeesten, I. (2017). "Design and Evaluation of Virtual Environments Mechanisms to Support Remote Collaboration on Complex Process Diagrams," Information Systems (66), pp. 59–81.

PricewaterhouseCoopers. (2021). "Seeing Is Believing - How Virtual Reality and Augmented Reality Are Transforming Business and the Economy." (https://www.pwc.com/gx/en/technology/publications/assets/how-virtual-reality-and-augmented-reality.pdf, accessed April 4, 2023).

Psotka, J. (2013). "Educational Games and Virtual Reality as Disruptive Technologies," Journal of Educational Technology & Society (16:2), pp. 69–80.

Rauschnabel, P. A., Felix, R., Hinsch, C., Shahab, H., and Alt, F. (2022). "What Is XR? Towards a Framework for Augmented and Virtual Reality," Computers in Human Behavior (133), p. 107289.

Recker, J. (2010). "Opportunities and Constraints: The Current Struggle with BPMN," Business Process Management Journal (16:1), pp. 181–201.

Recker, J. (2013). Scientific Research in Information Systems: A Beginner's Guide, Springer.

Riemer, K., Holler, J., and Indulska, M. (2011). "Collaborative Process Modelling-Tool

Analysis and Design Implications," in Proceedings of the 19th European Conference on Information Systems (ECIS), Helsinki, Finland.

Roldán, J. J., Crespo, E., Martín-Barrio, A., Peña-Tapia, E., and Barrientos, A. (2019). "A Training System for Industry 4.0 Operators in Complex Assemblies Based on Virtual Reality and Process Mining," Robotics and Computer-Integrated Manufacturing (59), pp. 305–316.

Saredakis, D., Szpak, A., Birckhead, B., Keage, H. A. D., Rizzo, A., and Loetscher, T. (2020). "Factors Associated with Virtual Reality Sickness in Head-Mounted Displays: A Systematic Review and Meta-Analysis," Frontiers in Human Neuroscience (14:03), p. 96.

Sassone, P. G., and Schaffer, W. A. (1978). Cost-Benefit Analysis: A Handbook (Vol. 182), Academic Press New York.

Savvides, S. (1994). "Risk Analysis in Investment Appraisal," Project Appraisal (9:1), pp. 3–18.

Schmidt, R., and Nurcan, S. (2009). "BPM and Social Software," in Business Process Management Workshops: BPM 2008 International Workshops, Springer, pp. 649–658.

Schneeberger, S. J., and Habegger, A. (2020). "Ambidextrie–Der Organisationale Drahtseilakt: Synergie Zwischen Exploration Und Exploitation Als Voraussetzung Für Die Digitale Transformation," Digitale Transformation und Unternehmensführung: Trends Und Perspektiven Für Die Praxis, Springer, pp. 105–144.

Schuir, J., Pöhler, L., and Teuteberg, F. (2022). "Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality-Marktes am Beispiel Oculus," HMD Praxis der Wirtschaftsinformatik (59:1), pp. 261–279.

Schumann, M., and Linß, H. (1993). "Wirtschaftlichkeitsbeurteilung von DV-Projekten," in Informationsmanagement, Springer, pp. 69–92.

Smith, E. A. (2001). "The Role of Tacit and Explicit Knowledge in the Workplace," Journal of Knowledge Management (5:4), pp. 311–321.

Sonnenberg, C., and Vom Brocke, J. (2012). "Evaluations in the Science of the Artificial–Reconsidering the Build-Evaluate Pattern in Design Science Research," in International Conference on Design Science Research in Information Systems, Springer, pp. 381–397.

Straatmann, T., Schumacher, J.-P., Koßmann, C., Poehler, L., Teuteberg, F., Mueller, K., and Hamborg, K.-C. (2022). "Advantages of Virtual Reality for the Participative Design of Work Processes: An Integrative Perspective," WORK - A Journal of Prevention, Assessment and Rehabilitation, pp. 1765–1788.

Sutton, S. G., and Arnold, V. (2013). "Focus Group Methods: Using Interactive and Nominal Groups to Explore Emerging Technology-Driven Phenomena in Accounting and Information Systems," International Journal of Accounting Information Systems (14:2), pp. 81–88.

Thies, L., Strohmeyer, C., Ebert, J., Stamminger, M., and Bauer, F. (2019). "Compiling VR/AR Trainings from Business Process Models," in Adjunct Proceedings of the 2019 IEEE International Symposium on Mixed and Augmented Reality , pp. 181–186.

Triaa, W., Gzara, L., and Verjus, H. (2017). "Exploring the Influence of Social Software on Business Process Management," IFAC-PapersOnLine (50:1), pp. 12968–12978.

Venable, J. (2006). "The Role of Theory and Theorising in Design Science Research," in Proceedings of the First International Conference on Design Science in Information Systems and Technology (Desrist 2006), pp. 1–18.

Venable, J., Pries-Heje, J., and Baskerville, R. (2016). "FEDS: A Framework for Evaluation in Design Science Research," European Journal of Information Systems (25), pp. 77–89.

Venkatesh, V., Brown, S. A., and Bala, H. (2013). "Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems," MIS Quarterly (37:1), pp. 21–54.

VHB (2015). "VHB-JOURQUAL3 : Teilrating Wirtschaftsinformatik." (https://vhbonline.org/fileadmin/user_upload/JQ3_WI.pdf, accessed April 4, 2023).

Vogel, J., Schuir, J., Koßmann, C., Thomas, O., Teuteberg, F., and Hamborg, K. (2021). "Let's Do Design Thinking Virtually: Design and Evaluation of a Virtual Reality Application for Collaborative Prototyping," in European Conference on Information Systems (ECIS), A Virtual AIS Conference, pp. 1–19.

Webster, J., and Watson, R. T. (2002). "Analyzing the Past to Prepare for the Future: Writing a Literature Review.," MIS Quarterly (26:2), xiii–xxiii.

Weichhart, G., Pirker, J., Gütl, C., and Stary, C. (2014). "3D Progressive Education Environment for S-BPM," in International Conference on Subject-Oriented Business Process Management, Springer, pp. 188–197.

West, S., Brown, R., and Recker, J. (2010). "Collaborative Business Process Modeling Using 3D Virtual Environments," in Proceedings of the 16th Americas Conference on Information Systems: Sustainable IT Collaboration around the Globe:, Association for Information Systems, pp. 1–11.

Wharton, C., Rieman, J., Lewis, C., and Polson, P. (1994). "The Cognitive Walkthrough Method: A Practitioner's Guide," in Usability Inspection Methods, pp. 105–140.

Williams, A. J., and Smith, W. C. (1990). "Involving Purchasing in Product Development," Industrial Marketing Management (19:4), pp. 315–319.

Winter, R. (2010). "Interview with Jay F. Nunamaker, Jr. on 'Toward a Broader Vision of IS Research," Business & Information Systems Engineering (2), pp. 321–329.

Wohlgenannt, I., Simons, A., and Stieglitz, S. (2020). "Virtual Reality," Business & Information Systems Engineering (62:5), pp. 455–461.

Van Wyk, E., and De Villiers, R. (2009). "Virtual Reality Training Applications for the Mining Industry," Proceedings of AFRIGRAPH 2009: 6th International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa, pp. 53–64.

Zenner, A., Makhsadov, A., Klingner, S., Liebemann, D., and Krüger, A. (2020). "Immersive Process Model Exploration in Virtual Reality," IEEE Transactions on Visualization and Computer Graphics (26:5), pp. 2104–2114.

Appendix

Bibliographic information[1]	Outlet	Ranking	
		WKWI	VHB
Pöhler, L., Kus, K. and Teuteberg, F. (2021). "Understanding pandemic dashboard development: A multi-level analysis of success factors," in Proceedings of the Sixteenth International Conference on Wirtschaftsinformatik (WI), Duisburg-Essen.[2]	Wirtschaftsinformatik (Conference)	A	C
Kus, K., **Pöhler, L.**, Kajüter, P., Arlinghaus, T. and Teuteberg, F. (2022). "Vaccination Dashboard Development during COVID-19: A Design Science Research Approach," in: Proceedings of the Seventeenth International Conference on Wirtschaftsinformatik (WI), Erlangen-Nürnberg.[3]	Wirtschaftsinformatik (Conference)	A	C
Müller, K., Hamborg, K. C., Straatmann, T., Schumacher, J., Koßmann, C. Teuteberg, F., **Pöhler, L**, Schaper, N., Depenbusch, S., Schüler, T., Izdebski, K., Deppen, K., Neyer, C. and Meyer zu Venne, W. (2023). "Sozio-digitale Innovation durch partizipative Prozessgestaltung im virtuellen Raum," in: Digitalisierung der Arbeitswelt im Mittelstand 3, Nitsch, V., Brandl, C., Häußling, R., Roth, P., Gries, T., Schmenk, B. (eds), Springer Vieweg, Berlin, Heidelberg..[4]	Book chapter	-	-

[1] Prof. Dr. Frank Teuteberg critically reflected on the structure, methodological design and content of all contributions and participated in form of constructive feedback for improvement.
[2] The author of this dissertation and Mr. Kevin Kus worked in equal parts on this paper.
[3] Mr. Kevin Kus and the author of this dissertation worked in equal parts on this paper. They were responsible for the idea development, methodological design, prototyping and evaluation. Mrs. Patricia Kajüter and Mr. Tim Arlinghaus supported in evaluation and integration of reviewer feedback.
[4] All authors contributed equally to the book chapter.

Appendix 1. Bibliographic information and ranking of out-of-scope papers

Part B: Research Contributions

Contribution A: Advantages of Virtual Reality for the Participative Design of Work Processes: An Integrative Perspective

Contribution A	
Title	Advantages of Virtual Reality for the Participative Design of Work Processes: An Integrative Perspective
Authors	Tammo Straatmann Jan Schumacher Cosima Koßmann Ludger Pöhler Frank Teuteberg Karsten Müller Kai-Christoph Hamborg
Year	2022
Medium	Journal
Outlet	WORK - A Journal of Prevention, Assessment & Rehabilitation
Ranking	JIF: 1.802
Bibliographic information	Straatmann, T., Schumacher, J.-P., Koßmann, C., Poehler, L., Teuteberg, F., Mueller, K., and Hamborg, K.-C. (2022). “Advantages of Virtual Reality for the Participative Design of Work Processes: An Integrative Perspective,” WORK - A Journal of Prevention, Assessment and Rehabilitation, pp. 1765–1788.
Identification	DOI: 10.3233/WOR-211260 ISSN: -
Link	https://content.iospress.com/articles/work/wor211260
Abstract	BACKGROUND: The participative design of work processes is hampered by as-yet unresolved challenges. A root cause is seen in high information-pass-on-barriers. Virtual Reality (VR) may have a significant potential to overcome these challenges. Yet, there is no systematic understanding of which advantages provided by VR can support the participative design of work processes. OBJECTIVE: The present study aims to assess the potential of VR to support the participative design of work processes by conducting an integrative literature review identifying the advantages of VR in general work contexts and mapping them to known challenges in participative design of work processes. METHODS: The integrative literature review was conducted based on 268 sources of which 52 were considered for an in-depth analysis of the advantages offered by VR. RESULTS: The resulting conceptual framework consisted of 13 characteristic-related advantages (e.g., immersion, interactivity, flexibility) and 10 effect-related advantages (e.g., attractivity, involvement, cost efficiency) which readily address known challenges in the participative design of work processes. CONCLUSION: Mapping the advantages of VR to the challenges in participative design of work processes revealed a substantial potential of VR to overcome high information-pass-on-barriers. As such, employing VR in work process design initiatives represents a fruitful avenue for the promotion of prevention and employee health.

Contribution B: Closing Spatial and Motivational Gaps: Virtual Reality in Business Process Improvement

	Contribution B
Title	Closing Spatial and Motivational Gaps: Virtual Reality in Business Process Improvement
Authors	Ludger Pöhler Frank Teuteberg
Year	2021
Medium	Conference Proceedings
Outlet	29th European Conference on Information Systems (ECIS 2021)
Ranking	VHB-JOURQUAL 3: B WKWI: A
Bibliographic information	Pöhler, L. and Teuteberg, F. (2021). "Closing Spatial and Motivational Gaps: Virtual Reality in Business Process Improvement.," in Proceedings of the European Conference on Information Systems (ECIS), A Virtual AIS Conference.
Identification	DOI: - ISSN:
Link	https://aisel.aisnet.org/ecis2021_rp/151/
Abstract	In times of growing digitization and globalization, Business Process Improvement is becoming increasingly important. Prior to improving processes, weak points in existing business processes must be identified. However, such improvement and change processes are often hindered by a weak participation due to lacking motivation among employees. At the same time, conventional process modelling languages do not allow for including the environment in finding weak points. To address these barriers, we compared the use of Virtual Reality to a conventional 2D-paper presentation. For this purpose, we carried out an experiment, in which weak points of a picking process should be identified. We examined and compared the number of identified weak points and the user perceptions in both environments. It turned out that Virtual Reality applications are an effective and motivation increasing alternative to conventional instruments for use in Business Process Improvement.

Contribution C: Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality-Marktes am Beispiel Oculus

Contribution C	
Title	Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality-Marktes am Beispiel Oculus
Authors	Julian Schuir Ludger Pöhler Frank Teuteberg
Year	2022
Medium	Journal
Outlet	HMD Praxis der Wirtschaftsinformatik
Ranking	VHB-JOURQUAL 3: D WKWI: B
Bibliographic information	Schuir, J., Pöhler, L., and Teuteberg, F. (2022). “Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality-Marktes am Beispiel Oculus,” HMD Praxis der Wirtschaftsinformatik (59:1), pp. 261–279.
Identification	DOI: 10.1365/s40702-021-00817-w ISSN: 1436-3011
Link	https://link.springer.com/article/10.1365/s40702-021-00817-w
Abstract	Virtual Reality (VR) hat in den vergangenen Jahren erhebliche technologische Fortschritte verzeichnet und begonnen, sich im Endverbrauchermarkt zu etablieren. Insbesondere Facebooks Tochterunternehmen Oculus erzielte mit der Quest 2 hohe Absatzzahlen, wodurch das Produkt zum bisher meistverkauften VR-Headset avancierte. Gleichzeitig entfachte sich aufgrund Oculus neuer Datenschutzbestimmung, welche die Gerätenutzung an ein Facebook-Konto bindet, jedoch ein kontroverser Diskurs unter Datenschützern. Endverbraucher stehen seither vor einem Dilemma. Sie müssen sich zwischen der Preisgabe sensibler Daten an Facebook im Falle der Nutzung kostengünstiger Oculus-Geräte und höheren Preisen anderer VR-Headsets entscheiden. In Deutschland führte diese Entwicklung zu einer Vertriebspause der Quest 2, da das Bundeskartellamt ein Missbrauchsverfahren gegen Facebook eingeleitet hat. Im vorliegenden Beitrag wird auf Basis einer Conjoint-Analyse untersucht, wie deutsche Endverbraucher dieses Dilemma wahrnehmen. Hierzu werden die relativen Wichtigkeiten von Datenschutzbestimmungen, Hardwareeigenschaften und Preisen für Kaufentscheidungen miteinander verglichen. Es ergeben sich drei verschiedene Marktsegmente mit unterschiedlichen Kaufentscheidungsheuristiken. Aus diesen Erkenntnissen resultieren sieben Handlungsempfehlungen, die VR-Herstellern, -Entwicklern, -Nutzern und Verbraucherschützern bei der verantwortungsvollen und weitreichenden Diffusion der VR-Technologie im Endverbrauchermarkt helfen sollen.

Contribution D: Enabling Collaborative Business Process Elicitation in Virtual Environments

	Contribution D
Title	Enabling Collaborative Business Process Elicitation in Virtual Environments
Authors	Ludger Pöhler Julian Schuir Simon Lübbers Frank Teuteberg
Year	2020
Medium	Conference Proceedings
Outlet	Lecture Notes in Business Information Processing
Ranking	VHB-JOURQUAL 3: C WKWI: -
Bibliographic information	Pöhler, L., Schuir, J., Lübbers, S., and Teuteberg, F. (2020). "Enabling Collaborative Business Process Elicitation in Virtual Environments," in Lecture Notes in Business Information Processing (Vol. 391), B. Shishkov (ed.), Springer, Cham, pp. 375–385.
Identification	DOI: 0.1007/978-3-030-52306-0_27 ISSN: 978-3-030-52306-0
Link	https://link.springer.com/chapter/10.1007/978-3-030-52306-0_27
Abstract	With increasingly globalized markets and the growing digitization, business process redesign has steadily become more important in recent years. Despite its increasing relevance, the actual process elicitation still poses a major challenge as global distribution of company locations makes the carrying out of process modelling workshops difficult, and especially novices have problems with the modeling itself. To meet these challenges, virtual reality based systems were estimated to be an efficient and promising way. Consequently, this paper deals with the development of a virtual reality application for participatory process modelling. Using the Design Science paradigm, the work identifies issues occurring in business process elicitation from the literature and translates them into meta-requirements. With the help of these meta-requirements, design principles were derived that were considered in the development. Using these design guidelines, a prototype to enable collaborative process elicitation in VR was developed and subsequently evaluated by a focus group.

Contribution E: Let’s Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling

	Contribution E
Title	Let’s Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling
Authors	Ludger Pöhler Julian Schuir Pascal Meier Frank Teuteberg
Year	2021
Medium	Conference Proceedings
Outlet	42nd International Conference on Information Systems (ICIS 2021)
Ranking	VHB-JOURQUAL 3: A WKWI: A
Bibliographic information	Pöhler, L., Schuir, J., Meier, P., and Teuteberg, F. (2021). “Let’s Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling,” in Proceedings of the International Conference on Information Systems (ICIS), Austin, Texas.
Identification	DOI: - ISSN: 978-1-7336325-9-1
Link	https://aisel.aisnet.org/icis2021/user_behaivors/user_behaivors/12/
Abstract	Business process modeling plays a fundamental role in organizations that are restructuring their processes to meet the challenges of increasing digitalization and globalization. However, the geographic distribution of process stakeholders, the abstract non-contextual modeling languages, and the resulting low motivation to participate make process modeling difficult. In this paper, we present a design science research approach that resolves these problems using virtual reality. Based on empirical evidence, we first developed design principles to increase employee engagement. Subsequently, a virtual reality application was generated, that enables the placing of process models in realistic and immersive working environments. We developed the application continuously in four evaluation cycles and finally tested it in terms of usefulness in three field studies. The results of this study contribute to more context awareness in business process management and provide design knowledge for future industrial virtual reality applications.

Contribution F: Unfolding Benefits of Virtual Reality for Workplace and Process Design based on Utility Effect Chains

	Contribution F
Title	Unfolding Benefits of Virtual Reality for Workplace and Process Design based on Utility Effect Chains
Authors	Ludger Pöhler Frank Teuteberg
Year	2022
Medium	Conference Proceedings
Outlet	26th Pacific Asia Conference on Information Systems (PACIS 2022)
Ranking	VHB-JOURQUAL 3: C WKWI: B
Bibliographic information	Pöhler, L. and Teuteberg, F. (2022). “Unfolding Benefits of Virtual Reality for Workplace and Process Design Based on Utility Effect Chains,” in Proceedings of the Pacific Asia Conference on Information Systems (PACIS), A Virtual AIS Conference.
Identification	DOI: - ISSN: -
Link	https://aisel.aisnet.org/pacis2022/32
Abstract	The advent of sophisticated virtual reality (VR) technologies has the potential to transform the way organizations design their workplaces and processes. The evaluation of artifacts for this use case is mostly limited to short-term effects at the task level. This paper therefore aims to unfold the benefits of using VR for workplace and process design in the long run at the division and corporate level. For this purpose, we applied a mixed methods approach. First, we identified benefits by using a VR software artifact for workplace and process design in field studies. Second, we extended the initial benefits by applying utility effect chains resulting in benefits at the division and corporate level. The resultant utility effect chain model reveals that, in addition to functional benefits, the hedonistic user experience of VR can also provide economic benefits for organizations in the long term.

Contribution G: Suitability- and Utilization-based Cost-Benefit Analysis: A Techno-Economic Feasibility Study of Virtual Reality for Workplace and Process Design

	Contribution G
Title	Utilization-based Cost-Benefit Analysis: A Techno-Economic Feasibility Study of Virtual Reality for Workplace and Process Design
Authors	Ludger Pöhler Frank Teuteberg
Year	2023
Medium	Journal
Outlet	Information Systems and e-Business Management (ISeB)
Ranking	VHB-JOURQUAL 3: C WKWI: B
Bibliographic information	Pöhler, L. and Teuteberg, F. (2023): "Suitability- and Utilization-based Cost-Benefit Analysis: A Techno-Economic Feasibility Study of Virtual Reality for Workplace and Process Design," Information Systems and e-Business Management (ISeB), pp. 1–41.
Identification	DOI: 10.1007/s10257-023-00658-8 ISSN: -
Link	https://link.springer.com/article/10.1007/s10257-023-00658-8
Abstract	Virtual reality (VR) is increasingly being used in the corporate environment. Benefits of using VR have also already been identified in the area of combined workplace and process design. However, whether organizations should invest in VR for this use case is only feasible with knowledge of all operational and strategic costs and benefits. Since previous methods for simulating the costs and benefits of information systems rely strongly on prior knowledge and experience, these approaches are not effective for novel technologies such as VR for less tested use cases due to low empirical databases. In order to provide a more accurate cost–benefit analysis (CBA) of the use of VR for strategical planning like workplace and process design, design science research is applied. Subsequently, by including task technology fit theory, a suitability- and utilization-based CBA method emerged. The contribution thus provides, first, a systematically derived method for quantification and simulation of costs and benefits of strategic VR use in organizations. Second, it provides concrete insights into factors influencing profitability of an investment in a specific VR system for strategic planning projects for workplace and process design based on case study insights.

Contribution H: Das Extended-Reality-Canvas – Wie können Unternehmen XR-Projekte erfolgreich implementieren?

Contribution H	
Title	Das Extended-Reality-Canvas – Wie können Unternehmen XR-Projekte erfolgreich implementieren?
Authors	Ludger Pöhler Fabian Belda Frank Teuteberg
Year	2023
Medium	Journal
Outlet	HMD Praxis der Wirtschaftsinformatik
Ranking	VHB-JOURQUAL 3: D WKWI: B
Bibliographic information	Pöhler, L., Belda, F., and Teuteberg, F. (2023). "Das Extended-Reality-Canvas–Wie können Unternehmen XR-Projekte erfolgreich implementieren?," HMD Praxis der Wirtschaftsinformatik, pp. 1–20.
Identification	DOI: 10.1365/s40702-023-00959-z ISSN:
Link	https://link.springer.com/article/10.1365/s40702-023-00959-z
Abstract	Extended-Reality-Technologien (XR-Technologien) haben in den vergangenen Jahren einen erheblichen technologischen Fortschritt erfahren. In der Arbeitswelt wird ihre Implementierung mit zahlreichen Vorteilen, wie z. B. Produktivitätssteigerungen, geringeren Kosten und verbessertem Lernen assoziiert. Dennoch stellt die disruptive XR-Technologie Unternehmen bei der Implementierung vor zahlreiche Herausforderungen, die sich von einer veränderungsresistenten Unternehmenskultur bis hin zu gesundheitlichen Bedenken bei Mitarbeitern erstrecken. Unternehmen fehlt es an Instrumenten, die das Innovationsmanagement bei der Überwindung dieser Hürden spezifisch unterstützen. Im vorliegenden Beitrag wurde daher das XR-Canvas entwickelt, das als Workshop-Instrument zur Spezifikation und Implementierung von XR-Projekten in Unternehmen eingesetzt werden kann. Es integriert elf Handlungsfelder in den Dimensionen Technologie, Organisation, Umwelt und Anwender, die auf Basis einer systematischen Literaturrecherche identifiziert wurden. Abgeleitet von Experteninterviews werden final Handlungsempfehlungen gegeben, wie das Canvas die XR-Implementierung unterstützen und die organisationale Ambidextrie fördern kann. Somit liefert dieser Beitrag einerseits Erkenntnisse, welche Faktoren die XR-Implementierung beeinflussen. Andererseits liefert er eine Innovationsmethode, um diese Einflussfaktoren strukturiert in XR-Anwendungsfällen zu spezifizieren.