A DESIGN SCIENCE AND IMPLEMENTATION FRAMEWORK FOR STUDYING INTERRUPTIONS AND ITS APPLICATION IN A DENTAL CLINIC

By

Carsten Ziegler

Dipl.-Ing., Technische Universität Berlin, 2005

A Dissertation

Submitted to the Faculty of the

J. B. Speed School of Engineering of the University of Louisville

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy in Industrial Engineering

Department of Industrial Engineering

University of Louisville

Louisville, Kentucky

May 2024

A DESIGN SCIENCE AND IMPLEMENTATION FRAMEWORK FOR STUDYING INTERRUPTIONS AND ITS APPLICATION IN A DENTAL CLINIC

By

Carsten Ziegler
Dipl.-Ing., Technische Universität Berlin, 2005

A Dissertation Submitted on

March 19, 2024

to the following Dissertation Committee:

Dissertation Director, Pratik Parikh, Ph.D.

John S. Usher, Ph.D.

Gail DePuy, Ph.D.

Mahesh Gupta, Ph.D.

ACKNOWLEDGMENTS

Foremost, I would like to express my sincere gratitude to my dissertation advisor, Dr. Pratik Parikh, for his excellent guidance, great support, encouragement, and knowledge he has given me over the past 3 years.

I would like to thank Dr. Gupta for sharing his unique perspective, guidance, and support. In addition, I would also to like to acknowledge my committee members, Dr. John S. Usher and Dr. Gail DePuy, for their encouragement and suggestions.

I would also like to thank the faculty and staff of the Department of Industrial Engineering for their support throughout the years.

Finally, I am grateful to my family and friends for the constant love and support. This work would not have been possible without all of you.

ABSTRACT

A DESIGN SCIENCE AND IMPLEMENTATION FRAMEWORK FOR STUDYING INTERRUPTIONS AND ITS APPLICATION IN A DENTAL CLINIC

Carsten Ziegler

March 19, 2024

Interruptions during dental treatment are frequent, and often have detrimental effects on quality of care, patient safety and processing times, and have an impact on provider satisfaction and performance. Interruptions can significantly increase the cognitive load on dental providers, making it hard for them to concentrate on complex procedures. Frequent interruptions also disrupt the workflow in general, leading to delays in treatment, which can reduce the overall throughput of a clinic. Unfortunately, there is no comprehensive approach to collectively (i) analyze interruptions in dental healthcare, (ii) design an intervention, and (iii) implement and sustain it.

This research proposes a comprehensive conceptual framework designed to address this challenge. Our framework, which we term Design Science and Implementation Research (DSIR), comprises Design Science Research (DSR) and the most advanced framework in implementation science – the Consolidated Framework of Implementation Research (CFIR). Our framework fills a gap between the existing frameworks from DSR, which address creation of new innovations and interventions, and CFIR, which focuses on

pursuing process steps that extend from the creation of an innovation throughout its practical application, without going into much detail about how it should have been designed. We illustrate the application of DSIR in a dental healthcare setting.

Our first contribution (Chapter 2) provides details of our proposed DSIR framework that provides guidance on how to design an innovative intervention and implement the created artifact in a real-world environment. We discuss the four stages (Environment, Knowledge Base, Design and Development, and Implementation) and five cycles (Relevance, Rigor, Design-Implementation, Change Management, and Sustainability) in the DSIR.

Our second contribution (Chapter 3) illustrates the practical application of the DSIR framework. Here we study interruptions in a dental clinic, analyze the data, design an intervention to reduce the negative impact of interruptions on the clinic, its staff and patients, especially by reducing interruption frequency, and pilot it for several months. We analyze the impact of the intervention on processing time and provider satisfaction. The total number of interruptions dropped by 72.5% after the intervention; short interruptions (<1min) reduced by 86%. A provider survey indicated substantial improvement due to the intervention in perceived workload, provider work satisfaction, patient safety and stress.

There are several implications of our findings to practice. We demonstrate the importance of cohesively analyzing interruptions, and designing and implementing an intervention, adhering to our proposed framework from start to finish. We are also able to show a real-world example of its application, which was a first in a dental setting, that created a quieter and more structured treatment environment resulting in a substantial elimination of interruptions during critical procedures in that clinic.

Reflecting on the results, we found that future work could further improve the efficiency of our intervention by enabling it to automatically provide additional timing information to staff members or otherwise interact with them. Implementing our approach at other dental clinics, regionally and globally, would help evaluate its robustness and help generalize our findings beyond this clinic.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Interruptions in dental healthcare

While costly innovations in dentistry and dental technologies attempt to provide definitive dental care, they can be cost prohibitive. In Germany, most of these technologies are only available to private / self-pay patients or those that make a significant financial contribution of their own beyond the public healthcare system's coverage. These patients do not only expect quality care on a technical level ('what is delivered'), but also value how their treatments are delivered regarding their safety, comfort, and well-being, and also require to be served in a timely fashion.

While medical errors in general pose a major threat to patient safety, errors in dentistry are certainly less likely to cause death, but they could still lead to potentially painful and expensive additional treatments.

Interruptions in dental clinics are frequent and can contribute to errors in dentistry. By interruptions, in this dissertation we mean anything external that takes a dental providers' attention away from a task or communication activity they are engaged in a part of their work (including interruptions caused by dental assistants).

One of the co-authors had the opportunity to help build and grow a dental clinic in Germany over the past 15 years. Interruptions at this clinic, especially during critical steps of longer treatments, often caused major losses of time (30 minutes and more). This could lead to missed dental caries during examination, preparation, fillings, or dental chairside CAD/CAM manufactured parts falling out due to wetness or other mistakes during the application of adhesives, to name a few. All of them would likely result in unnecessary loss of more tooth substance and discomfort for the patient. These instances generate waste for everyone as the patient would need to spend extra time either at once (should the problem be noticed right away) or during another appointment. In either case, the practice would need to redo the treatment, spending precious time and costly dental materials, resulting in either overtime (with a negative impact of staff job satisfaction) or a loss of revenue due to a cancelled appointment.

While there is a growing body of research involving interruptions in healthcare, in general, we are not aware of any research that pertains to the specific challenges faced by dental practitioners due to interruptions to their treatments. While we knew prior to this study that interruptions were affecting operations at this dental clinic, we neither knew what caused these interruptions nor what type of intervention to design and implement.

Our objective in this study was to apply a new conceptual framework and to address the following questions:

Q1. What are the types of interruptions during dental treatments?

Q2. What is the impact of interruptions on the dental treatment (e.g., wait times and provider satisfaction)?

Q3. What intervention(s) would help mitigate the most detrimental interruptions, and what steps are needed to implement it?

As we did not find an appropriate framework in academic literature that would allow us to address Q1-Q3, we first proposed a new conceptual framework that we call the Design Science and Implementation Research (DSIR) framework. We now summarize the key contributions of our work.

1.2 Contribution 1: DSIR framework for studying interruptions

As Contribution 1, we introduce the DSIR framework - a comprehensive conceptual framework that consolidates constructs found in Design Science Research (DSR) and in Implementation Science – to guide in studying interruptions and to help prevent implementation failure.

The framework is based on a cyclical model that recognizes the iterative nature of design, implementation, and learning. It is composed of four interrelated stages:

- Environment (problem identification in the application domain);
- Knowledge base (the scientific base and provider expertise);
- Design and development (artifact design and evaluation); and
- Implementation (management support and long-term resource allocation.

Each stage is connected to other appropriate stages, via continuous feedback cycles promoting refinement and adaptation. These cycles include:

- Relevance (ensures designed artifacts are relevant to their environment);

- Rigor (ensures designed artifacts are correlating to the knowledge base);
- Design-Implementation (bridges gap between design and implementation);
- Sustainability (ensures long-term usefulness); and
- Change Management (accompanies necessary organizational changes that come with implementing the artifact)

Our approach aims to avoid the risk of failure faced by up to 2/3 of organizations' efforts to implement change (Burnes, 2004) by assessing the extent to which implementation can be successful in a given environment, to optimize intervention benefits, and to prolong sustainability of an intervention. We propose a framework that provides a structured, rigorous, and iterative methodology for conducting DSR, along with a strategy for implementation.

1.3 Contribution 2: Illustrating the use of DSIR at a German dental clinic

To illustrate the use of our framework developed in Chapter 2, we conduct a pre-post study that analyzes the types and sources of interruptions during dental treatments in a single German dental clinic (Q1). We assess the impact of the observed interruptions by surveying the affected providers to address Q2 and develop and implement an intervention (Q3) to mitigate the impact of the interruptions during critical treatment procedures. Because this study was deemed as a quality improvement project at this clinic, it was classified as Non-Human Subjects Research (NHSR) by University of Louisville's Institutional Review Board.

During the pre-study we observed all 6 providers in this clinic over a period of 100 working hours. To record the observed interruptions, we adapted a data form based on existing literature from the hospital environment and created a survey to collect information about provider satisfaction. The data was subsequently analyzed to identify the relevant sources of interruptions, identify potential patterns and to understand the perceived impact of the observed interruptions on the affected providers.

After building a consensus with the providers at this clinic on a promising intervention and its implementation, we adhered to a ramp-up period to allow for questions and to establish protocol modification for daily operations. Once the new process appeared stable, we proceeded with the post-study observation for another 100 working hours under similar conditions as during the pre-study, accompanied by the same survey questions, which were expanded by a small set of additions to collect information about the perception of the intervention.

Results indicate that substantial improvement can be achieved at this clinic by enabling the affected dental providers to select periods when they do not want to be interrupted and to communicate their choice by a switchable electronic sign that displays a corresponding message at the entrance to the respective treatment room. We observe a significant drop in interruption quantity and a noticeable increase in staff satisfaction.

We now explain the development of this framework in Chapter 2 of this dissertation and show a practical application in a dental setting in Chapter 3.

CHAPTER 2

DEVELOPMENT OF A DESIGN SCIENCE AND IMPLEMENTATION FRAMEWORK (DSIR) FOR INTERRUPTIONS IN HEALTHCARE

2.1 Introduction

In dental healthcare, procedural interruptions pose a significant challenge, affecting dental provider concentration and, thus, procedural efficiency and patient safety. Procedural efficiency can be seen in part as a matter of productivity, which is becoming more important in healthcare, given funding restraints and an aging population. Productivity revolves around two fundamental principles: (a) throughput rate (i.e., flow of entities through the system in a given time) and (b) the minimization of variation from all sources, including quality and timing (Schmenner, 2015).

In a dental clinic, productivity broadly translates into the flow of paying patients (excluding warranty claims, etc.) during the scheduled working hours (Devaraj, Ow, and Kohli, 2013). Improving productivity in dentistry – or healthcare, in general – requires focusing on the social aspect of change as well as the technical (Johnson M, Burgess N, and Sethi S, 2020). Patient flow is influenced by a patient's length of visit which is in turn influenced by the speed with which other patients are treated. Lack of flow potentially causes overcrowding in the waiting area, cancellation of appointments and or excessive stress on healthcare staff due to overtime etc.

Many interventions and innovations fail to be implemented, even with highly developed execution plans, as many contextual factors can work against implementation in the real world (Damschroder et al., 2022). Our goal – and the focus of this work – is to introduce an enhanced framework that we will call DSIR – Design Science and Implementation Research, that includes constructs from a synthesis of existing theories, primarily Design Science Research (DSR) and the Consolidated Framework for Implementation Research (CFIR).

Interruptions can occur from various sources like colleagues, patients, equipment malfunctions or even external noises. Each interruption has its implications and risks, which vary depending on the procedure being performed. From minor inconveniences to major procedural errors, interruptions can have a range of adverse outcomes. For example, an interrupted dental provider may forget a step in a procedure which may lead to patient complications or fail to properly document the procedures performed, leading to inaccurate invoicing or legal issues should a patient make claims for maltreatment. Also, provider work satisfaction degrades because of too frequent unnecessary interruptions.

Currently – according to research – the most common avoidance strategies involve manual signs and vests/tabards. However, each of these has its limitations, particularly in how effectively they convey the urgency or necessity of avoiding interruptions. The existing solutions are often static and cannot be adapted in real-time to the needs of the dental procedure, making them less effective. Due to these limitations, there is a compelling need for a framework that would aid in not only analyzing existing interruptions, but also designing an intervention that is both effective and efficient, more flexible and context aware. For this purpose, we explore existing frameworks in Design

Science Research (DSR) and Implementation Research (described by the consolidated framework for implementation research, CFIR) to propose our own generic framework.

2.2 Background on Design Science Research and Implementation Research

It is critical to understand the differences between Design Science Research (DSR) and Implementation Research (described by the consolidated framework for implementation research, CFIR). We first provide a brief summary of both DSR and CFIR, before sharing existing conceptual frameworks for both.

The conception and maturation of DSR is evidence to the evolving understanding of research methodologies that combine the creation of artifact with the creation of knowledge. The roots of DSR can be traced back to Simon's "The Sciences of the Artificial" (1996) where he postulated the idea of design as a science. Since then, many scholars have contributed to shaping DSR into a research methodology. March and Smith (1995) were crucial in articulating the types of artifacts – constructs, models, methods, and instantiations – that DSR could produce, while Hevner et al (2004) set forth a paradigm that outlines guidelines for conducting DSR, including the relevance of the problem addressed, the contribution to knowledge, and the rigorous evaluation of the design artifact. The application of DSR has expanded beyond the boundaries of information systems into areas such as healthcare and education, proving the versatility of its principles.

Implementation research on the other hand tries to identify and address care gaps, support practice change, and enhance quality and equity of healthcare. Implementation is the critical gateway between an organizational decision to adopt an intervention and the routine use of that intervention; it also covers the transition period during which the stakeholders become increasingly skillful, consistent, and committed in their use of an intervention (Klein, Sorra 1996). One of the approaches to achieving implementation is via the perceived features of the healthcare innovation itself – in addition to effectiveness (Klaic et al., 2022). An early theory, Diffusion of innovations (Rogers EM, Cartano DG 1962), identified features of innovations that make their adoption more or less likely, namely their relative advantage, trialability, observability, compatibility with the existing system and complexity. Trialability refers to being able to test the innovation on a small scale or in a pilot study.

Numerous conceptual frameworks exist for a multitude of applications. Below we review a few of the most popular Design or Implementation framework.

2.2.1 Brixey's Framework

Brixey (2014) created one of the few frameworks related to interruptions in healthcare (Figure 2.1).

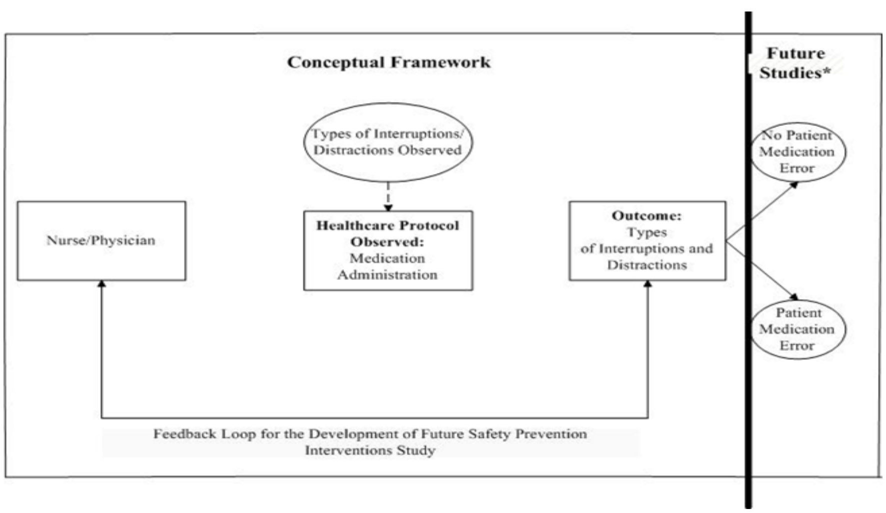


Figure 2.1: Brixey's conceptual framework for interruptions

It intends to cover multiple parameters, different types of interruptions and has a feedback loop to support a 'future' intervention study. This framework remains very basic and addresses interruptions only – there is no implementation, and no solutions are addressed directly.

2.2.2 Omachonu's Framework

Omachonu (2010) designed a framework for healthcare innovations (Figure 2.2). It has a comprehensive view of innovations in healthcare relating to the patient, with a highlight on quality metrics. This framework can help balance innovations to address all aspects but has no handle on interrelation complexity (impact of an innovation on other areas as well as cost and outcome). Unfortunately, it also has no direct application in interruptions research.

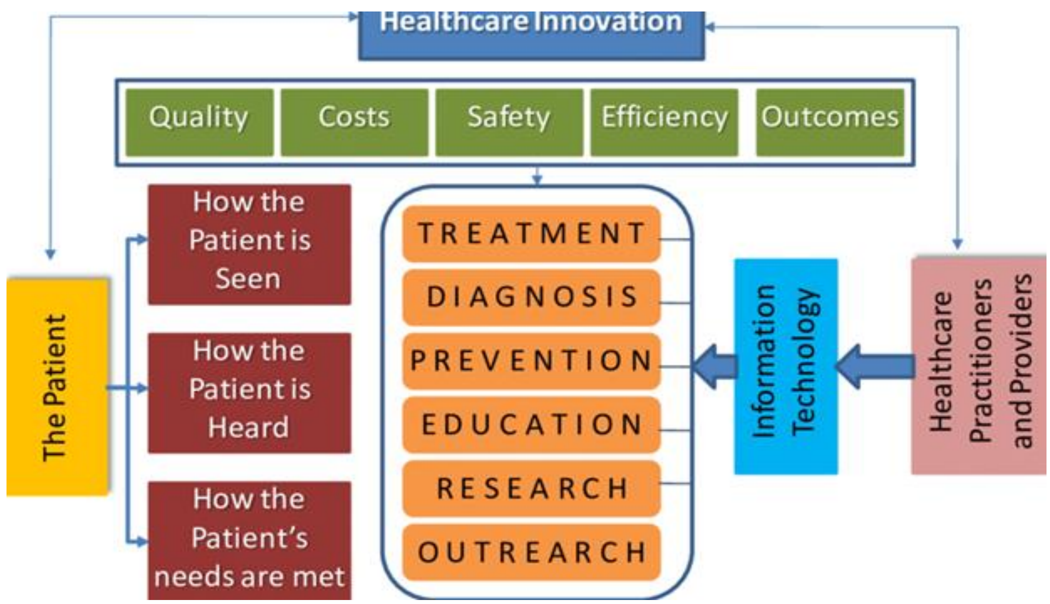


Figure 2.2: Omachonu's healthcare innovation framework

2.2.3 Nurumal's Framework

Nurumal's (2017) conceptual framework of factors influencing nurses' intentions to stay (job retention) includes a detailed view on job satisfaction motives in the healthcare industry (Figure 2.3). It adds a staff view to the context. However, it is focused only on job satisfaction and is not easily generalizable or extendable to broader application.

Figure 2.3: Nurumal's conceptual framework (nurse job retention)

2.2.4 Hevner's DSR Framework

The most promising existing framework for the purpose of this work is the Design Science Research (DSR) framework of Hevner (2004). It bridges theory and practice to address real world problems (Figure 2.4). DSR focuses on understanding organizational phenomena in context and on advancing research by creating and evaluating artifacts, that solve real-world problems, while advancing the knowledge base as well (Gregor and Hevner, 2013).

The purpose of Hevner's DSR is two-fold: to solve "authentic field problems" (van Aken et al. 2016) and second to work towards generic interventions that can be deployed in similar and related contexts (Denyer et al., 2008; Holmstrom, Ketokivi and Hameri, 2009). DSR is promoted as bridging theory – practice gaps by considering the relationships between context, intervention, mechanisms, and outcomes (CIMO). It is laid out for continuous improvement, creating flexible artifacts in a structured approach. DSR currently lacks didactic materials (Bagni et al. 2024) and it does not cover the implementation of the created artifacts.

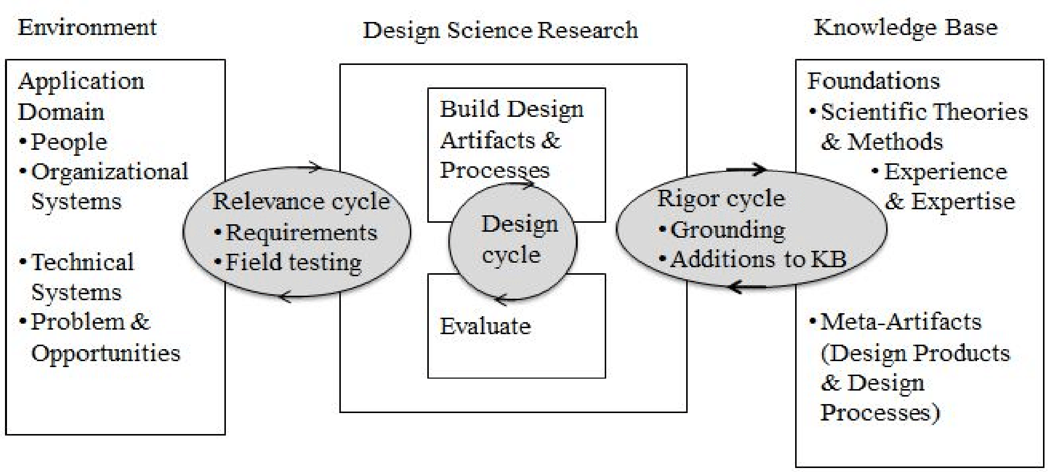


Figure 2.4: Hevner's DSR framework

2.2.5 McAlearney's Framework

McAlearney's (2016) conceptual framework for intervention implementation in a medical environment considers many factors which are relevant in a larger organization

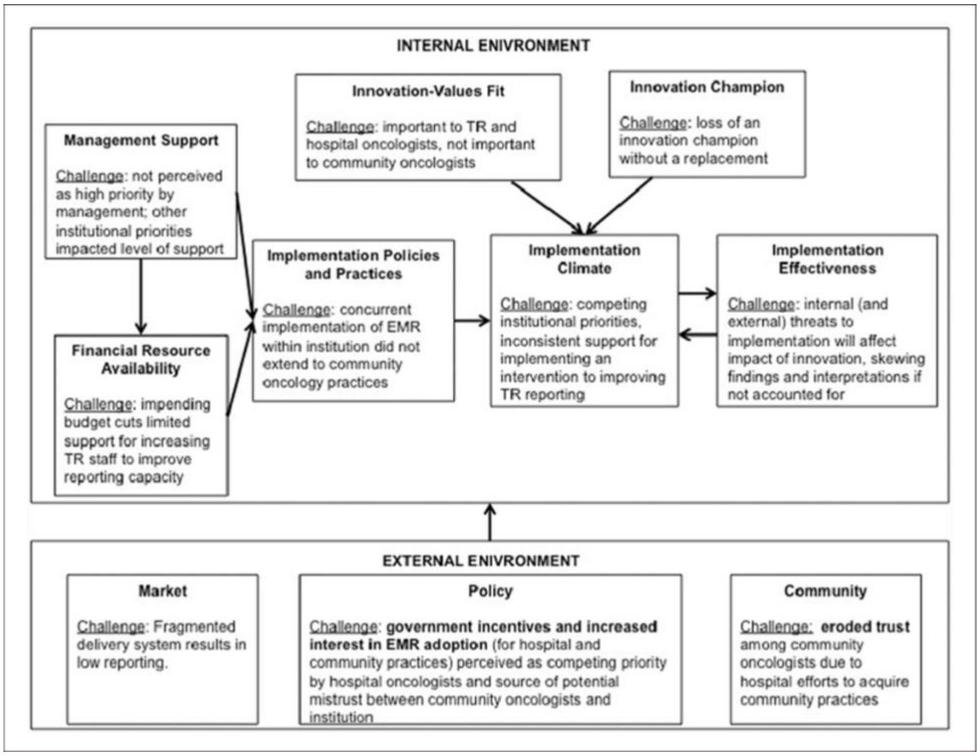


Figure 2.5: McAlearney's conceptual framework for (medical) intervention

such as a hospital environment (Figure 2.5). Even though its practical application in the context of its original publication was relating to the implementation of a medical intervention (on patients), the framework does include a number of valuable elements that can be applied to other implementation tasks in the medical environment.

2.2.6 Damschroder's CFIR Framework

The more recent Consolidated Framework of Implementation Research (CFIR) proposes 7 attributes of interventions: intervention source, evidence strength and quality, relative advantage, adaptability, trialability, complexity, and design quality and packaging, the latter referring to the 'presentation' of the intervention and its user accessibility (Damschroder et al., 2009, 2022).The CFIR is 'meta-theoretical' – it includes constructs from a synthesis of existing theories originally compiled by Damschroder et al. (2009) and recently updated in Damschroder et al. (2022). It specifies a list of constructs within general domains that are believed to influence implementation. It does not explicitly provide solid guidance to develop an artifact.

Novel characteristics in the CFIR constructs that need to be considered are as follows:

- the relative advantage of implementing an intervention vs. an alternative solution (Gustafson et al. 2003);
- the degree to which an innovation can be adapted, tailored, refined to meet local needs (Greenhalgh, et al. 2004; Fixsen et al. 2005); and

- the ability to test the innovation on a small scale in the organization (Greenhalgh et al., 2004) and the ability to undo the implementation (i.e., trialability), if necessary (Feldstein, Glasgow 2008).

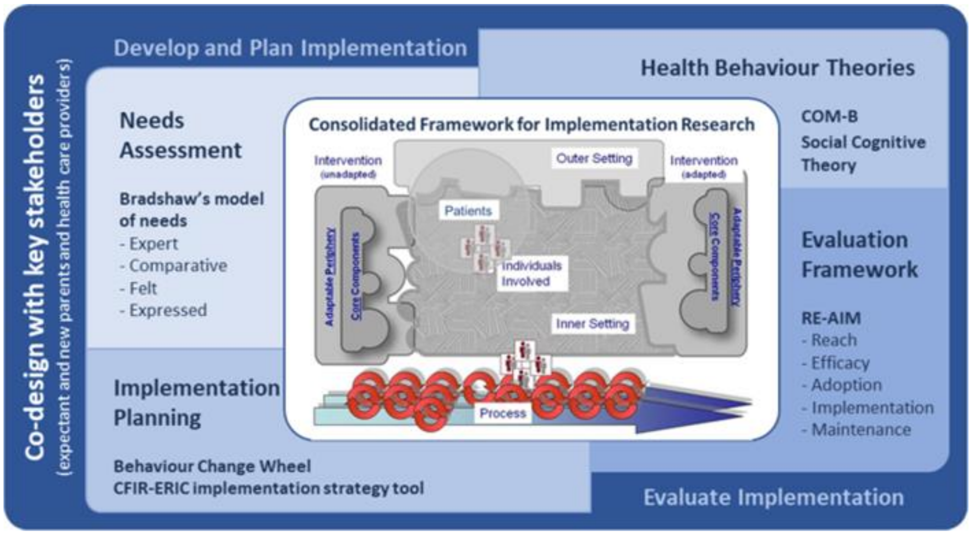


Figure 2.6: CFIR Framework (Damschroder, 2009)

2.2.7 Peffers' Framework

Following Hevner's guidelines, Peffers et al. (2007) introduced a six-stage model for executing DSR projects, on which Sein et al. (2011) expanded by introducing methods for artifact evaluation and reflection on design processes, highlighting the importance of also assessing artifacts within their operational context.

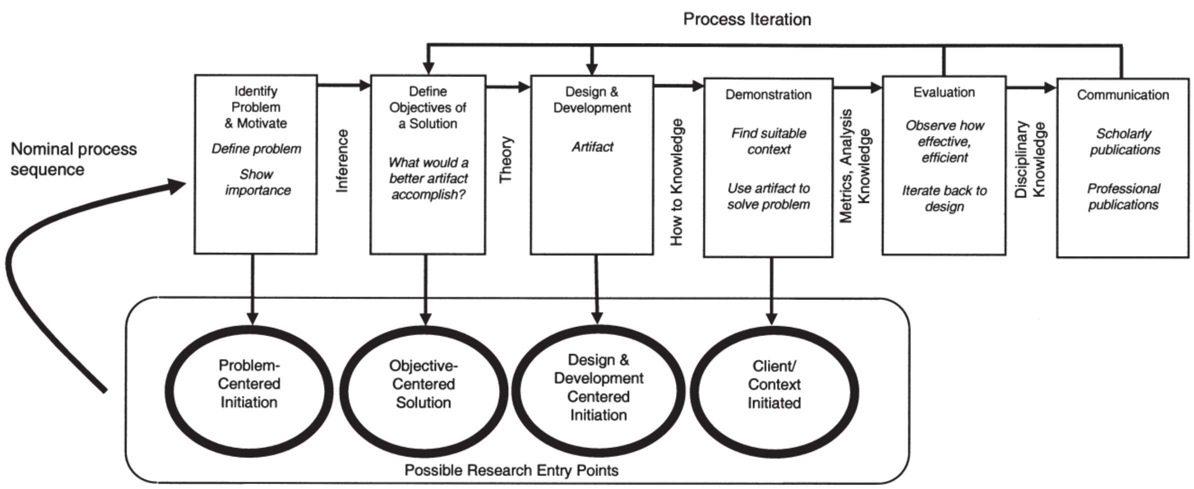


Figure 2.7: Peffers' DSRM

2.2.8 Gaps in Existing DSR and CFIR Frameworks

Despite the expansive growth and application of DSR and CFIR, there remain gaps in these frameworks. The following gaps were observed in the DSR framework:

- Practical implementation guidance: The framework primarily focuses on the theoretical support of DSR, providing a high-level overview of the process. However, it lacks detailed, step-by-step guidance for the practical implementation of DSR projects.

- Stakeholder engagement: While the framework addresses the importance of engaging with stakeholders to ensure the relevance of research outcomes, it does not address the complexity of managing stakeholder relationships to ensure ongoing engagement throughout the project lifecycle and how to deal with changes in stakeholder priorities or project scope.
- Evaluation rigor: It emphasizes the importance of rigorously evaluating artifacts, but it does not provide much detail on specific evaluation methods and criteria. This gap can lead to challenges in finding evaluation strategies that are both rigorous and relevant to the artifact's context.

The following gaps were observed in the CFIR framework:

- Limited focus on artifact design: CFIR provides an extensive set of constructs that influence implementation effectiveness, but it does not specifically focus on the design process of the artifact itself. This leaves designers and researchers looking for more guidance on how to systematically incorporate user needs, technological capabilities, and contextual factors into the design and development stage.
- Iterative development and prototyping: The framework primarily addresses the broader context of implementation without going into the specifics of iterative design and development processes that are crucial in artifact design, such as prototyping, user testing, and refinement based on user feedback.
- Technological innovation: CFIR was originally developed to be widely applicable across various types of interventions and contexts. As a result, it may not fully address the specific challenges and opportunities presented by rapidly evolving

technological landscapes. It lacks guidance on integrating technology into artifact design, while considering their implications for implementation.

A review of those frameworks relevant and somewhat applicable to this dissertation revealed that only a limited number of those focus on interruptions and innovation in healthcare. Among those that address implementation, the goal is to implement medical procedures or protocols towards patient applications, not to implement changes or innovations on a business process level. None provide a feasible approach to the specific problem discussed in this dissertation. To fill the identified gaps, our proposed framework aims to synthesize key constructs of the existing DSR and CFIR frameworks. It attempts to bridge the gaps between abstract theoretical discussions and the practical needs of those trying to implement DSR in a variety of contexts by including an explicit implementation cycle, which marks a significant evolution of the approach. We now outline the architecture of the expanded framework, detailing the iterative process to ensure the practical application of research findings in a healthcare setting.

2.3 Our Proposed Framework

Our proposed framework is termed Design and Implementation Science Research (DSIR). DSIR is rooted in the foundational guidelines and principles proposed by Hevner et al. (2004), which have since set a precedent for a systematic approach to developing and researching technology-based solutions, extended by a 'second root' in implementation research, to guide towards a successful long-term implementation of an innovation. Figure 2.8 illustrates the DSIR framework.

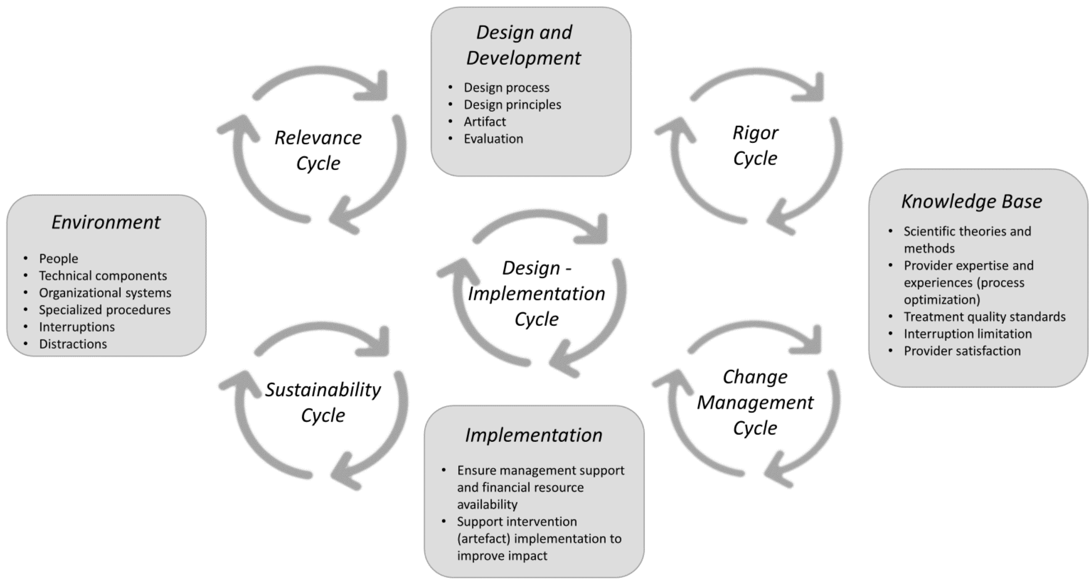


Figure 2.8: The Proposed DSIR Framework

The integration of DSR and CFIR frameworks addresses the gap between theory and practice. It encourages a dialogue between the utility-driven aspects of artifact design and the theoretical foundations that justify design choices. Additionally integrating ideas from CFIR are expected to influence the implementation success. Key stakeholders may perceive the DSIR developed artifact as an internally-developed solution to a problem vs. an externally-obtained product. Their close participation will help support the belief that an innovation will have the desired outcome, as they were part of creating the evidence.

This framework, therefore, seeks to combine the dual imperatives of DSR – to advance the boundaries of human knowledge through the creation of purposeful, innovative artifacts and to provide a structured approach to solving complex problems – with the concepts of intervention characteristics in the CFIR.

2.3.1 Elements of the DSIR Framework

The framework is based on a cyclical model that recognizes the iterative nature of design, implementation and learning in DSR. It is composed of four interrelated stages:

- Environment (problem identification in the application domain);
- Design and development;
- Implementation; and
- Knowledge base.

Each stage is connected to its neighbors, via continuous feedback loops and cycles promoting refinement and adaptation. These cycles include:

- Relevance;
- Rigor;
- Design-Implementation;
- Sustainability; and
- Change management.

We now present details of each stage and cycle below.

2.3.1.1 Environment Stage

The environment refers to the setting where artifacts will be deployed and used in, similar to Hevner 2004 and 2007. It encompasses all external elements that interact with or are affected by the artifact. Its main components are people. People are critical in the environment as their needs, capabilities, and limitations directly influence the design and effectiveness of an innovation, ensuring it is both useful and useable.

Another part of the environment is the technological infrastructure, consisting of the existing technologies and technical capabilities the artifact will interact with or build upon.

Organizational systems are the structures within which the artifact will operate in, including specialized processes and infrastructure of organizations. This component acknowledges that artifacts are not created in a 'vacuum' but rather parts of larger systems that include business processes and regulatory constraints.

Interruptions and Distractions play a significant role in this environment as well, as they can have a major impact on all of the previously mentioned items, keeping them from achieving full performance.

In summary, the DSIR environment is a fundamental concept in our framework, underscoring the importance of context in the design, deployment, and evaluation of artifacts.

2.3.1.2 Knowledge Base Stage

The knowledge base is another core component as it informs and supports the design, development, and implementation of innovative artifacts, adapted from Hevner (2004 and 2007). The knowledge base provides the theoretical and empirical foundation necessary to understand the problem domain and to design an effective artifact. Its key elements are:

- Theories and models, offering foundational knowledge that guides the design process to predict how an artifact will perform in certain environment.
- Frameworks, methods, and provider expertise with detailed guidance on specific aspects of design and evaluation to ensure rigorous testing and validation of a new artifact, making sure treatment standards are met.
- Empirical findings which are the results from experiments and research studies that provide insight into the effectiveness of certain designs and interventions to also ensure provider satisfaction.

To summarize, the knowledge base is a critical part of the DSIR framework, as it provides the necessary theoretical and empirical support for the DSIR process. It ensures that the creation of a new artifact is informed by a deep understanding of the existing knowledge. It also aims to contribute to it through the generation of new artifacts, new theories, and new empirical findings that enrich the existing body of knowledge.

2.3.1.3 Design and Development Stage

The design aspect of this framework refers to the methodologies, principles, and activities involved in the creation of an artifact. It focuses on how solutions can be developed that are both innovative and effective. Key components are:

- The artifact as the tangible output of the research and design processes.
- The design process including methodologies and approaches used to create and evaluate the artifact. It involves identifying the problem, understanding the requirements, prototyping, and iterative refinement. The design process is guided by creativity and rigor.

- The design principles as guidelines that direct the creation of an artifact. They ensure an efficient, reliable, and useable result, with minimal training required.
- The evaluation methods to assess the effectiveness, efficiency, and impact of the artifact. They include determining criteria for success or failure, selecting appropriate evaluation methods (such as experiments, simulations, or case studies).

By focusing on real-world problems and evaluating artifacts within their intended environment, the design and development stage ensures that research outputs are relevant and applicable, and they contribute to both theory and practice, offering new tools and techniques that can advance the field.

In summary, the design and development stage contains the core activities of this framework, focusing on the creation and evaluation of artifacts. It is through this stage that DSIR delivers its contributions, blending innovations with rigor to address complex problems and the unique challenges of this environment.

2.3.1.4 Implementation Stage

The implementation stage is seamlessly integrated into the broader DSIR process, serving as both culmination of the design effort and starting point for further iterations of artifact development. It focuses on the processes and factors that influence the deployment and adoption of the developed artifact. The implementation step draws on change management principles and agile methodologies to ensure that the artifact is not only implemented but also accepted and sustainably utilized effectively.

A detailed implementation strategy is necessary from the very beginning of a project:

- Preparation: Clear goals established and the scope of implementation defined before the determined resources for the project are secured.
- Execution: Artifact introduced into the target environment, ensuring proper integration with existing systems and workflows.
- Adoption: Stakeholders engaged through training, support, and possibly incentives to facilitate usage.
- Monitoring: Continuously tracking of performance and impact of the artifact, identifying issues, and assessing user feedback.
- Maintenance: Providing ongoing support, updating the artifact as necessary, ensuring sustainability.

While stakeholders play an important role throughout the DSIR process, this is particularly the case in the implementation stage. It allows for an active engagement with all relevant stakeholders to ensure that the artifacts are integrated into the operational environment as well as functionally aligned with the users' needs.

The implementation stage helps extend the focus beyond the creation and evaluation of an artifact to include its practical implementation. It bridges the gap between research and practice, ensuring an innovative artifact's translation into a tangible benefit for organizations and their stakeholders.

2.3.1.5 Relevance Cycle

The relevance cycle connects the environment (application domain) with the design activities. It ensures that the research remains grounded in real-world problems and that only relevant solutions are developed. This cycle helps identify problems and opportunities in the environment and at a later stage introduces the designed artifact into the environment to gather feedback for refinement. This cycle also takes care of continuous engagement with the stakeholders (providers) to ensure the research progress meets their needs and solves their actual problem.

2.3.1.6 Rigor Cycle

The rigor cycle connects the DSIR activities with the knowledge base. It has two applications:

- ‘analysis’ to ensure that the design research is based on scientific knowledge, making use of existing theories and methods to inform the design and evaluation of the artifact.
- ‘intervention’ following the artifact’s modifications along a pilot study and towards implementation. It also involves contributing new knowledge from the DSIR process back to the knowledge base.

These rigor cycle applications together emphasize the importance of using existing knowledge to ensure rigor in the research process and in contributing to the academic community.

2.3.1.7 Design-Implementation Cycle

In the center of the expanded framework is the iterative fine-tuning feedback loop between design and implementation. Each iteration is adjusted by the experiences and results of previous cycles, based on criteria established in the relevance cycle, encouraging a learning environment where artifacts are refined based on actual usage data and stakeholder feedback.

2.3.1.8 Sustainability Cycle

The sustainability cycle adds a critical dimension that ensures the long-term viability and continued effectiveness of an artifact within its application domain. The sustainability cycle bridges the gap between initial implementation and ongoing use, with a focus on maintaining and adapting the artifact to meet changing needs and conditions. This cycle interacts closely with both the environment (application domain) and the implementation stage, emphasizing the artifact's life cycle beyond initial deployment.

Integrating this cycle in the DSIR framework enhances the model by explicitly acknowledging the importance of post-implementation activities in the success of the artifact. This cycle creates a feedback loop between the environment (where the artifact is used and has impact) and the implementation stage (where the artifact is initially deployed and integrated not practice). It encourages researchers to consider the full lifecycle of an artifact from the outset, planning beyond the creation and implementation but rather the long-term sustainability of the solution.

2.3.1.9 Change Management Cycle

The change management cycle introduces a structured approach to managing the organizational and behavioral changes associated with the adoption and integration of an artifact. This cycle focuses on the human and organizational aspects of change, ensuring that the transition to a new process is smooth, effective, and sustainable.

This cycle emphasizes the importance of organizational and human factors in the successful adoption of an artifact. It creates a bridge that not only facilitates the practical implementation of technological solutions but also feeds valuable insights and experience back into the knowledge base. It also highlights the cyclical nature of learning and adaptation in DISR where practical experiences inform theoretical knowledge and vice versa.

By considering change management as an integral part of the process, researchers can adopt a more holistic approach that addresses both the technological and the human aspects of implementing artifacts.

2.3.1.10 Summary

In summary, our proposed DSIR framework provides a novel approach to the design and implementation of research artifacts. By incorporating a dedicated implementation stage, this framework acknowledges the importance of real-world application and continuous improvement, setting the stage for a dynamic process of learning and adaptation in design science research.

2.3.2 Application of DSIR in a Dental Setting

We now illustrate the use of DSIR in healthcare in a specific dental clinic that was challenged with interruptions to the healthcare providers during treatments. This is where the utility, efficacy and feasibility of the new framework are showcased in a real-world context.

2.3.2.1 Application - Environment Stage

For our application the environment was a dental clinic in a suburb of Berlin, Germany. The ‘people’ concerned were 6 healthcare providers (3 dentists, 3 hygienists), multiple other staff members (assistants, receptionists) and several patients. ‘Technical components’ of relevance was the dental equipment used in patient treatment. The organizational system provided the framework for daily operations at the clinic, most important the staff and patient scheduling to provide for a smooth treatment process. ‘Specialized procedures’ in our case were the specific dental treatments performed on the patients. These procedures often faced distractions and interruptions from within the system.

Appropriate metrics and methods for assessing the environment had to be determined, as a reference for a systematic evaluation of an artifact against objectives to be able to evaluate data on artifact performance, usability, impact. We focused on measuring interruption frequency and duration, and surveyed providers to assess changes to their perceived stress levels and their overall satisfaction with the solution (Figure 2.9).

2.3.2.2 Application - Knowledge Base Stage

To ensure that the defined objectives are grounded in a theoretical foundation relevant to the problem domain(a dental clinic facing interruptions_ they need to be aligned with the knowledge base of scientific theories and methods, healthcare provider expertise and experience, treatment quality standards and any literature relevant to the specific problem domain.

A substantial literature review on interruptions in the healthcare environment was performed to better understand existing and previously tested solutions and the scientific results around their applications. These are shown as the relevance cycle in Figure 2.9.

Provider expertise and feedback from the staff to assess the artifact's usability, effectiveness and acceptability was collected in surveys before (Figure 2.9) and after the implementation together with their individual perceptions of being interrupted during their work, depicted in Figure 2.10 as a rigor cycle.

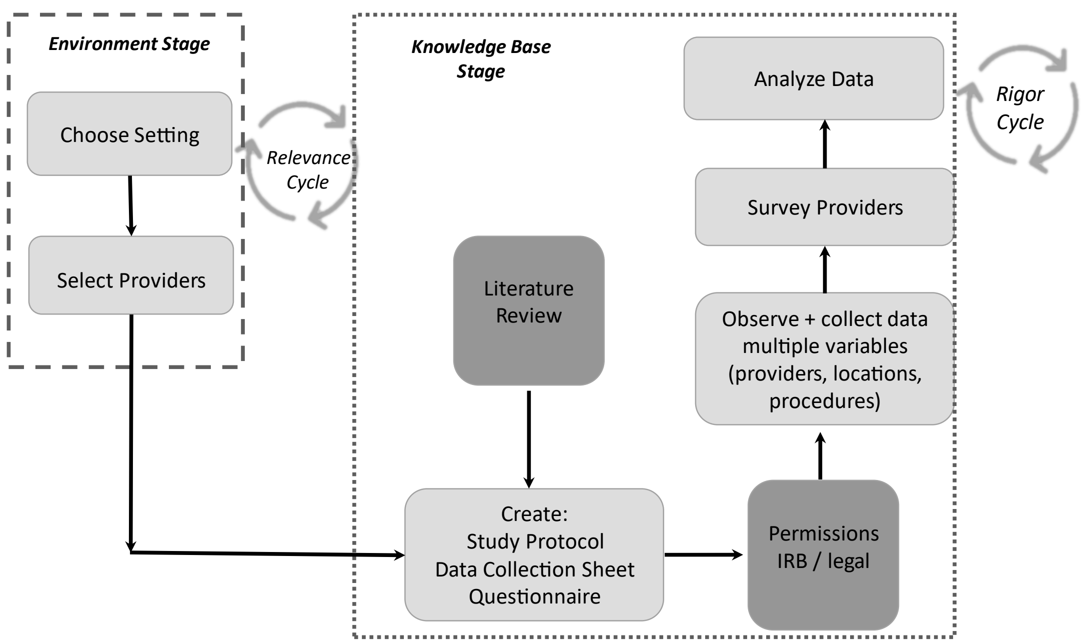


Figure 2.9: Environment and Knowledge Base Stages Relevant to the Dental Clinic

2.3.2.3 Application - Design and Development Stage

The artifact that represents the solution to the identified problem is designed and developed as an electronic sign approximately 20 inches wide and 5 inches high. It displays a flashing red text message in German equivalent to “DO NOT – ENTER” (the text switches from DO NOT to ENTER within a few seconds due to limited space for simultaneous display of characters). The sign can be remote controlled from the dental unit or nearby furniture by a battery-operated radio remote control that could be placed in a clear plastic bag for hygienic reasons.

An iterative approach to prototype development was chosen, which allowed for incremental refinement and adaptation based on user feedback, one of these refinements being the choice of a radio remote over an infra-red version, as this did not require the remote to be pointed in a certain direction while the receiver could be placed inside the wall behind the device.

Figure 2.10 shows this as ‘test, try, discuss’ step together with a design cycle. In our case, multiple remote-control handsets and receivers were purchased and installed, then the most suitable version identified before protection and positioning of the remote were discussed and optimized.

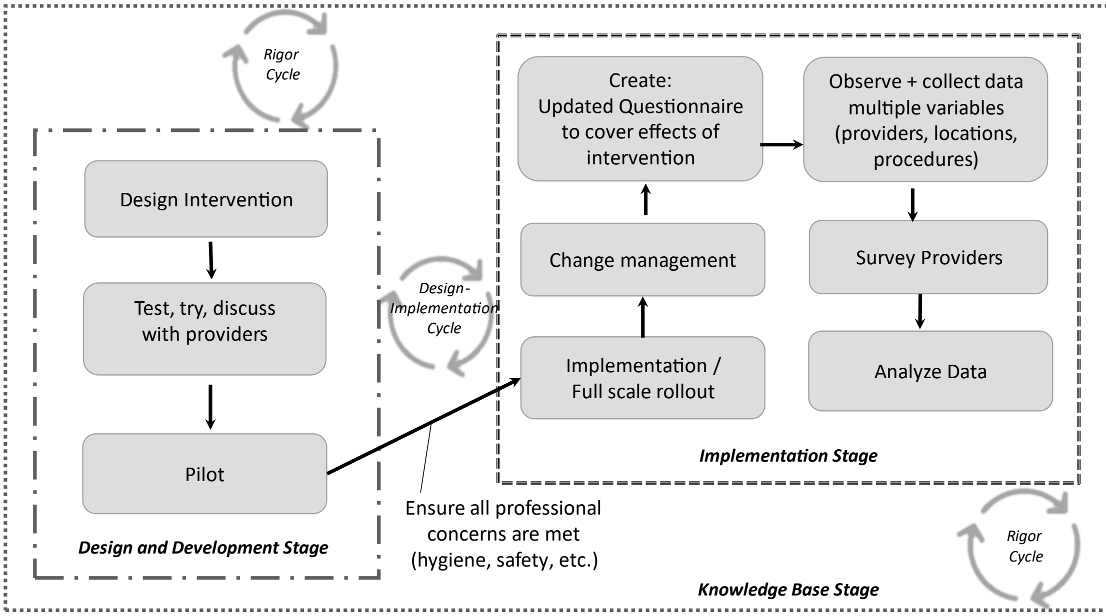


Figure 2.10: Develop to Implement

An initial assessment of the demonstration (pilot) outcomes, analyzing the data to evaluate the artifact's performance against the expectations was done after approximately 25%of the planned observation period, shown as another rigor cycle in Figure 2.10.

Using the findings from the initial assessment the artifact underwent minor refinement before being rolled out throughout the remainder of the clinic, adjusting features and protocols to better suit the clinic's needs.

2.3.2.4 Application - Implementation Stage

In preparation for implementation, the goal to significantly reduce interruption frequency during critical phases of treatments across all treatment rooms was established. After ensuring that all professional concerns (medical, hygiene, and safety) were met by the artifact, a pilot study was conducted to initially assess the artifact's performance and gather preliminary data, while incorporating feedback to refine the artifact before wider deployment (Rigor cycle in Figure 2.10).

The execution of the implementation was straightforward. The successfully-piloted system was rolled out to all treatment rooms, accompanied by change management efforts, such as staff training to ensure proper use of the artifact (Change Management cycle in Figure 2.10) The implementation was supported by all stakeholders as they quickly realized the utility of the artifact. In our specific case, management support and availability of financial resources was ensured, as one of the owners was part of the research team, while another was involved as the leading dental provider.

The use of the artifact was successfully monitored and maintained (Sustainability cycle) approximately 6 months beyond the data collection period described in the next chapter.

2.3.2.5 Application - Relevance Cycle

Stakeholders were identified as dentists, hygienists, dental assistants, and administrative staff. The researcher engaged with them to gather insights and requirements for a potential solution.

To understand the dental clinic's current workflow to identify the points where interruptions typically occur and the impact they have on operations, a workflow analysis was performed. Prior to the design of an intervention, data was collected and questionnaires were evaluated.

2.3.2.6 Application - Rigor Cycle

Changes in operational efficiency, such as time not lost to interruptions, overall throughput – less overtime, and staff (provider) satisfaction were measured.

2.3.2.7 Application - Design-Implementation Cycle

Initially a brief pilot implementation was done, running a pilot test of a single sign with remote control in action, documenting how the artifact performs in live operations and noting any initial issues or concerns. As no negative impact was noted and the staff was satisfied with the operation quickly, the next steps – collecting data - could be performed after a short period of time.

The installation was rolled out to more treatment rooms and the interactions of clinic staff and patients with the sign were observed and data was collected on its impact.

2.3.2.8 Application - Sustainability Cycle

For monitoring and maintenance purposes, processes for ongoing monitoring of the artifact's performance and its maintenance post-deployment were established, following an initial close observation that includes another set of data collection and surveys of the stakeholders to assess the improvement –and to detect potentially unanticipated issues created by the intervention. Figure 2.10 shows these as the steps from 'change management' to the end, finishing with an implementation rigor cycle.

The observation period during our study was only approximately 6 months. The selected technology made maintenance (battery changes) and continued hygiene easy to perform, but there are no long-term observations available.

2.3.2.9 Application - Change Management Cycle

The implementation is accompanied by change management efforts addressing the human and organizational aspects of introducing the remote-controlled sign, managing the change process to ensure smooth adoption. In this case, training of all staff members was essential to ensure proper use of the device and the unconditional acceptance of its displayed message by everyone involved.

A protocol was established together with the dental providers as to when the sign should be turned on – it was agreed to switch it on during the more critical stages of each treatment when an interruption would have the most detrimental impact.

2.4 Summary

In this chapter, we proposed the DSIR framework that provides a structured, rigorous, and iterative methodology for conducting DSR, along with an implementation. The methodology facilitates a deep understanding of complex problems, supports the creation of innovative artifacts, and emphasizes real-world application and continuous improvement.

The illustration of the new framework is integral to showing the practical value of our proposed DSIR framework, while a much more detailed presentation of this illustration can be found in the next chapter.

CHAPTER 3

INTERRUPTIONS IN A DENTAL SETTING AND EVALUATING THE EFFICACY OF AN INTERVENTION: A PILOT STUDY

3.1 Background

While constant innovations in dentistry and dental technologies (e.g., application of lasers, complex root canal treatments involving microscopes, iPad-controlled handpieces and expensive new filling materials, and the constantly evolving dental chairside CAD/CAM system) attempt to provide definitive dental care, they can be cost prohibitive. In Germany, most of these technologies are only available to private / self-pay patients or those that make a significant financial contribution of their own beyond the public healthcare system's coverage, which only spends 6% of its 2020 budget on dental care (KZBV Jahrbuch 2021). These patients do not only expect quality care on a technical level ('what is delivered'), but also value how their treatments are delivered regarding their safety, comfort, and well-being.

While medical errors in general pose a major threat to patient safety, with estimates reporting between 210,000 and 440,000 preventable deaths annually in the U.S. (James, 2013), others estimate that medical errors could be the third leading cause of death in the U.S. (Makary and Daniel, 2016). An error in dentistry is certainly less likely to cause death, but it could still lead to potentially painful and expensive additional treatments. In 2019 a study done by the German public health insurance system (MDK) showed, that 14,533 cases of possible medical malpractice had to be reviewed by experts, of which 1,055 cases (8.4%) were related to dentistry. Out of these a total of 392 cases (37.2% of the reviewed cases) turned out to be malpractice. Broken down further, 384 cases (134 of which had errors) were related to dental caries treatment and 308 cases (120 errors) were endodontics related. These statistics only cover major errors that were brought to the attention of a review board; the actual numbers – especially of smaller errors – are naturally higher. A study on implementation of an error reporting system suggested underreporting in health care close to 90% (Anderson and Abrahamson, 2017).

Interruptions in a dental clinic are frequent and can contribute to errors in dentistry. By interruptions, we mean anything external that takes a dental providers' attention away from a task or communication activity they are engaged in a part of their work (including interruptions caused by dental assistants). While working as a sales director for several Tier 1 Ag/Construction OEM suppliers, one of the co-authors had the opportunity to help build and grow a dental clinic in Germany. Interruptions at this clinic, especially during critical steps of longer treatments, often caused major losses of time (30 minutes and more). This could lead to missed dental caries during examination, preparation, fillings or dental chairside CAD/CAM manufactured parts falling out due to wetness or other mistakes during the application of adhesives, to name a few. All of them would likely result in unnecessary loss of more tooth substance and discomfort for the patient, or in rare cases, turn out as life threatening, if these parts fall out while the patient is asleep, and they might aspirate them. These instances generate waste for everyone as the patient would need to spend extra time either at once (should the problem be noticed right away) or during another appointment. In either case, the practice would need to redo the treatment, spending precious time and costly dental materials.

While there is a growing body of research involving interruptions in healthcare, in general, we are not aware of any research that pertains to the specific challenges faced by dental practitioners due to interruptions to their treatments. While we knew prior to this study that interruptions were affecting operations at this dental clinic, we neither knew what caused these interruptions nor what type of intervention to design and implement. Our objective in this exploratory, not hypothesis-driven, study was to address the following questions:

Q1. What are the types of interruptions during dental treatments?

Q2. What is the impact of interruptions on the dental treatment (e.g., wait times and provider satisfaction)?

Q3. What intervention(s) would help mitigate the most detrimental interruptions?

To address these questions, we used actual data collected at a German dental clinic to analyze the interruptions and their impact on two quantitative outcome measures: processing time and provider satisfaction survey. Based on this, we devised an intervention and piloted it at this dental clinic.

3.2 Methods

Our approach used direct observation to collect quantitative data to categorize interruptions to understand the impact on lost time and provider survey data to understand their impact on provider satisfaction. The study was approved by the University of Louisville's Institutional Review Board as a quality improvement project.

3.2.1 Setting

Due to regulations in Germany, only dentists are the key providers in German dental offices. They are allowed to delegate certain treatments to specially trained staff (like hygienists) that still need to work under their supervision (even though that supervision does not need to be constant or immediate). All work done by hygienists is the responsibility of the delegating dentist, while the practice owner is responsible for the work done by any employed dentists. Dental assistants are limited to performing tasks (on a patient) under direct supervision of a dentist, and their primary focus during a treatment is on preparing and handing tools and materials, use of suction to keep the treated area clean and dry, and to use the curing light (for polymerization). If time permits, they also handle the documentation on the computer.

The data for this study was collected at a dental clinic in a suburb of Berlin. The clinic was open 5 days a week, 12 hours per day and had 6 treatment rooms. It was staffed with 3 dentists, 3 hygienists (at different qualification levels), a receptionist and 8 assistants, who assisted dentists during the treatment or perform other tasks such as lab work, cleaning / disinfection, or sterilization procedures. Due to regulations, at any given time at least one of the dentists needed to be present in the clinic during operating hours.

The annual patient load was approximately 4,000 patients across all age groups. The patient load was spread almost evenly across the year. The dental equipment included 3 dental CAD/CAM computers and 3 milling machines, dental microscope, 3D cone beam, multiple dental lasers. The clinic had originally been set up without phones in treatment rooms or an intercom system to avoid interruptions and distractions during treatments.

Every dentist's treatment was performed by a team of one dentist and one or two dental assistants, who prepared the required materials and tools before the treatment, took care of the suction during the treatment, kept the area around the treated teeth clear and accessible and handed all necessary tools and materials to the dentist as required. After the patient had left, the assistant took care of cleaning and disinfecting the workplace including the patient's seat.

Hygienist usually worked alone, with their appointments lasting either 60 minutes (adults) or 30 minutes (children). Dentists' appointments (aside from check-ups and other minor tasks) were scheduled starting at 30 minutes with added 15-minute increments, with the longest treatments carrying on for up to 3 hours. Except for emergencies, all treatments are scheduled in advance; there were no walk-ins. Depending on X-ray and/or visual inspection, a preferred treatment (composite vs. inlay/crown) was determined and a time slot allotted according to the expected size and complication of the cavity. This time slot did not leave room for error or any "major" interruption. Deviations from the schedule resulted either in overtime or potentially treatments that needed to be cancelled.

A somewhat simplified view of the standard procedures (see Figure 3.1) illustrates the three key areas of treatment at this clinic that were observed to be sensitive to interruptions: periodontic treatment, root canal treatments, and dental chairside CAD/CAM inlays/crowns. This also has an immediate negative impact on provider satisfaction as having to 'unnecessarily' repeat the most critical steps due to an interruption also adds stress and workload, especially when repeating a critical step is associated with a large time loss (e.g., dental chairside CAD/CAM rework or having to redo a root canal). Table 3.1 summarizes the various types of interruptions and their sources considered in our study.

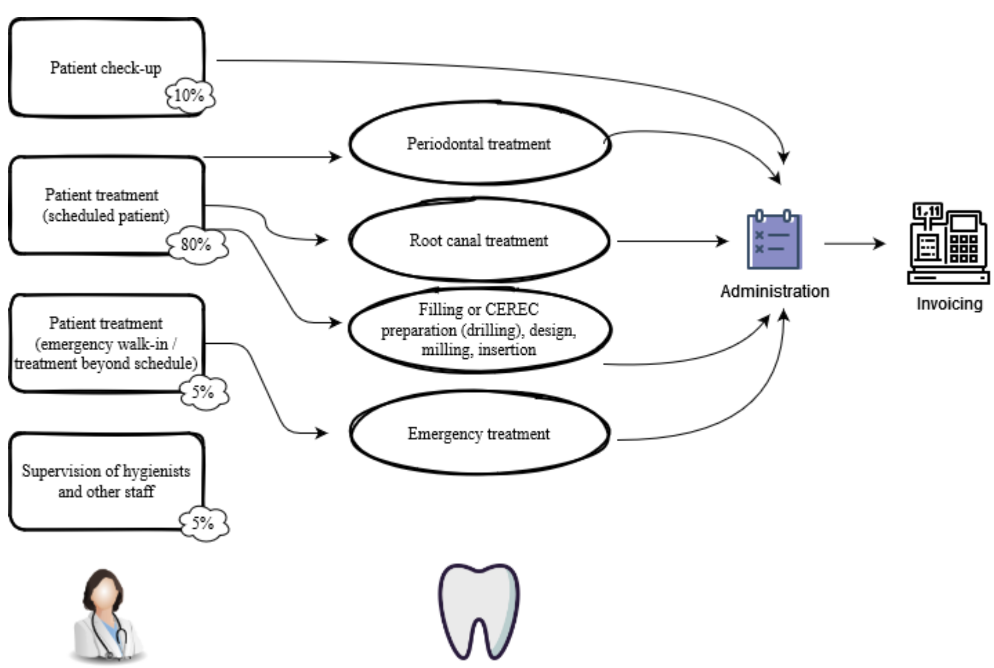


Figure 3.1: Key activities of a dentist

Table 3.1: Definitions of sources of interruptions assessed during dental treatment

Source	Definition
Provider	Interruptions resulting from other providers in the practice
Dental Assistants	Interruptions caused by assistants directly assisting the observed provider
Receptionist	Interruptions by the receptionist (authorization, phone call...)
Staff	Interruptions caused by dental assistants or other staff members not currently assisting the observed treatment
Other patient	Interruptions by a patient not currently attended to
Emergency	Occurrence of an emergency situation (medical)
Technical malfunction	Interruption due to equipment failure
Other	Miscellaneous interruptions not assigned to any other category

3.2.2 Participants

The clinic's three dentists and three hygienists took part voluntarily in direct observation and all responded voluntarily to a 25-question survey. The providers were 25 - 55 years old (average 40) and had 5 - 25 years of professional experience in their assigned positions (average 11.5 years). The participants were enrolled upon obtaining verbal consent (recorded by the first author) and had the opportunity to opt in or out of the study.

3.2.3 Data Collection

Two types of data were collected during the pre-intervention period; processing time and satisfaction survey.

For the processing time, the dentists and hygienists were observed during all hours of the workday (8 am - 8 pm) and all five days of the workweek to capture the nature of interruptions. A total of 100 hours of direct observation was conducted during March 7, 2022 - August 26, 2022. We adapted an observation data form based on existing literature (Brixey et al. 2007; Brixey et al. 2008; Parikh et al. 2016); see Appendix A. Data recorded for each interruption included task interrupted, a description of the interrupting event, location, source, medium, and time. The event description included reason for the interruption (task request, receive info, provide info, or authorize/sign a document) and whether relocation or change of task was required. Free form fields were used to record any observed impact of the interruption. To provide context for observed interruptions, we also noted the times and task categories the dentist/hygienist engaged in while being observed. Any interruption that had providers move their eyes away from the treated area was considered dissatisfactory due to the eye strain caused by significantly changing light brightness and focus.

All providers in the clinic were observed and data samples collected to classify the source of interruption, the task interrupted and the medium of interruption, while recording the day, time, and the duration of the interruption as well. Provider assistants were also included (wherever they were relevant - either as a part or the cause of interruption). Special attention was given to critical procedures and treatments with major impact on the care provision. In general, anything that had a significantly higher chance of harming the patient or creating disproportionate rework effort was considered critical. Patients in the clinic were not interviewed, nor was their care affected as the data collection is purely observational.

After enrolling the participant (dentist/hygienist), the observer (lead author) shadowed them noting the time when the participant changed tasks and capturing data from observed interruptions. The observer followed without verbal interaction except when on the first patient contact during the observation session, at which time the dentist would ask the patient for permission to have the observer watch the treatment. No patients declined to allow the observer to watch their treatment and no patient information was collected.

For the provider satisfaction data, we designed a 25-question survey. The purpose of this survey was to capture how interruptions were viewed by dentists and hygienists during dental treatments. Topics included how interruptions impact daily workload, time / wait time, patient safety, and care provider stress, as well as their perceived impact on patients. Additionally, questions about how interruptions occur, and the techniques used by providers to manage interruptions were included. (Appendix B) Participation was voluntary with each participant receiving a sheet of paper presenting the opportunity to anonymously complete the survey. In the survey instructions, interruptions were defined as "anything that takes your attention away from a task or communication activity that you were already engaged in as part of your job."

Post-intervention period: We used the same observation data form as used during the pre-study for the quantitative data. During November 1, 2022 – January 6, 2023, another 100 hours of direct observation was conducted. While we used the same 25-question survey used during the pre-intervention period, we added a few more questions that were directly related to the provider experience of using the intervention; see Appendix C.

3.2.4 Intervention

Our chosen intervention (upon discussions with the providers) was a flashing ‘Do not enter’ sign mounted above the entrance door of each treatment room (see Figure 3.2).

This light could be turned ON to alert staff and others indicating that a critical procedure is in progress which should not be interrupted (Figure 3.3)

A remote control was connected to each sign to turn the sign ON and OFF and was installed in each room within easy reach of the provider / assistant team in each room (Figure 3.4). Each remote control was placed into a plastic bag to ensure easy disinfection without damage to the devices. Each staff member was trained to understand the meaning of the sign, with special focus on the providers, to ensure the lights were turned on during procedures they had identified as ‘critical’ during the pre-intervention period.

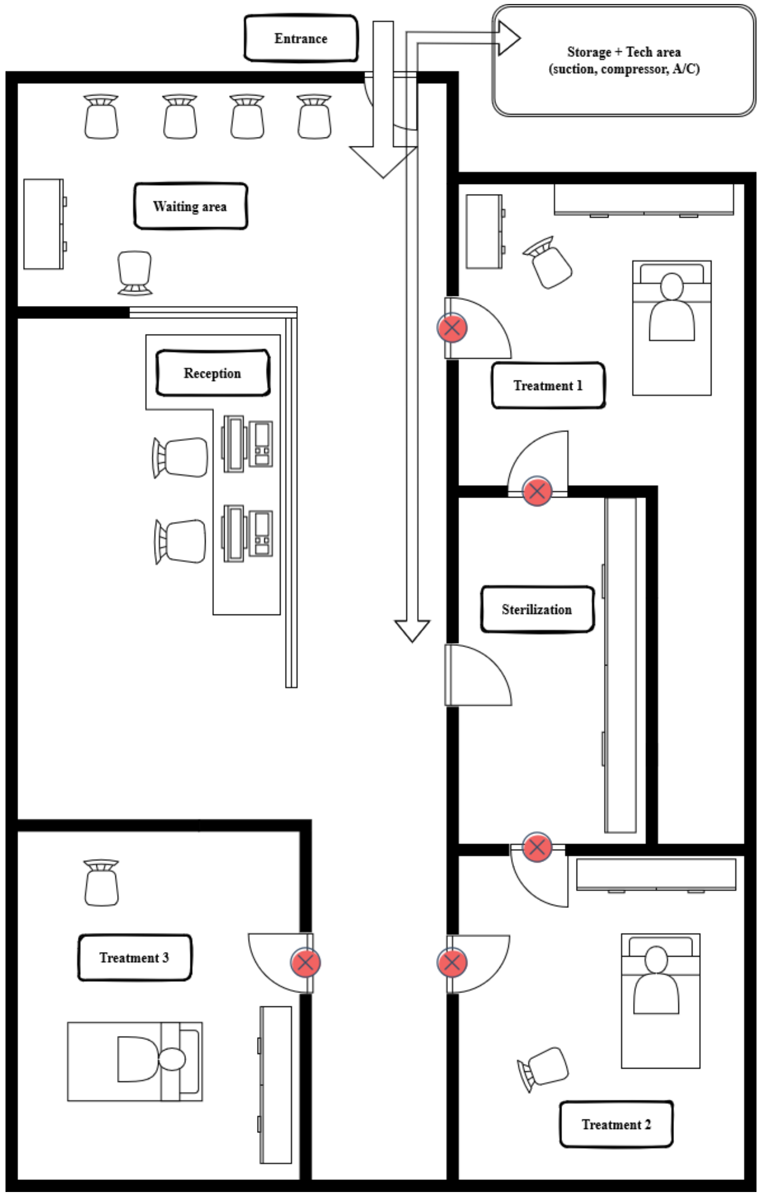


Figure 3.2: Layout of the rooms with positions of the signs (X)

After installation and training, a trial and ramp-up period of 4 weeks was used to acclimatize the providers on the new procedure. All staff members were given the opportunity to ask questions and report any issues during the 4-week period. Following these 4 weeks, the post-intervention data collection was conducted.

Figure 3.3: Sign above door (Kein in German refers to No or Do not Enter)

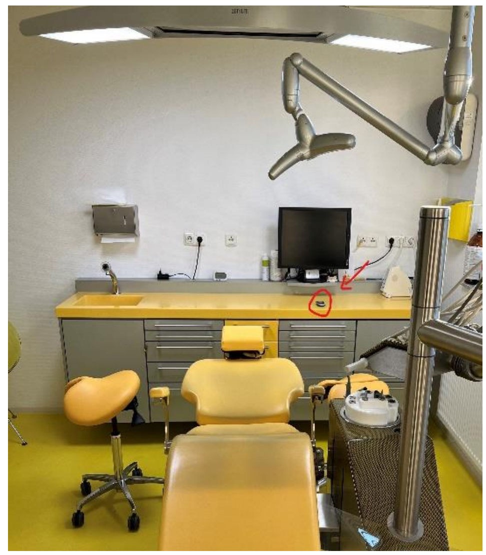


Figure 3.4: Position of the remote control

To illustrate how the intervention was used, consider as an example treatment: preparing and filling a tooth with a composite filling (simplified procedure shown in Figure 3.5). The light bulbs indicate when and for which approximate duration the sign would have been turned on.

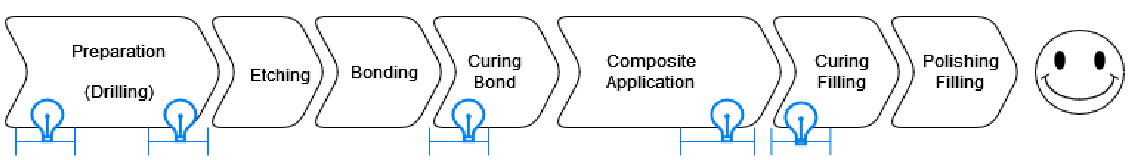


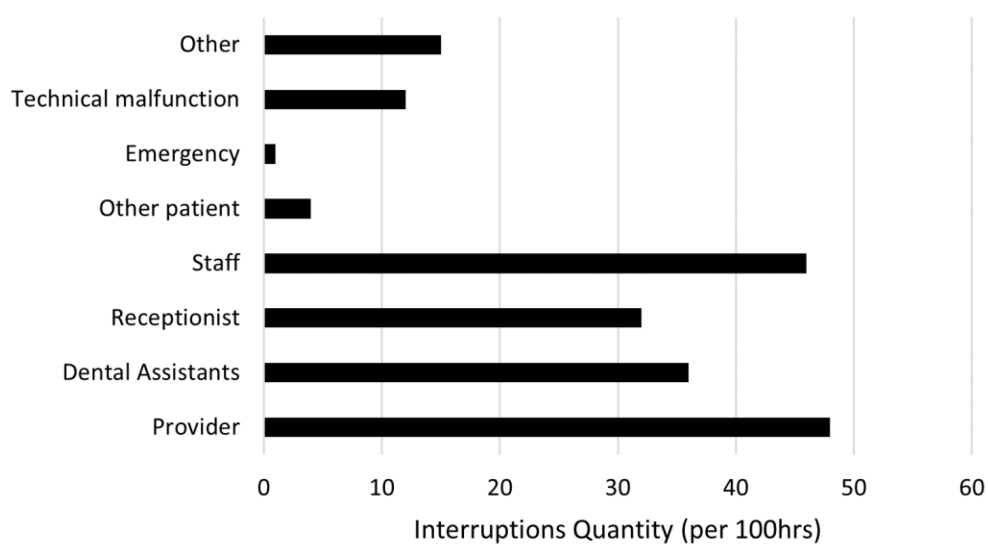
Figure 3.5: Illustration of the time periods the intervention was used during a sample treatment

3.3 Results

Pre-intervention period: During this period, a total of 194 interruptions were observed over 100 hours of data collection. At that time, the clinic did not have any formal policies for protecting providers from interruptions during this period.

Figure 3.6 shows a summary of observations by source of interruption. Most interruptions occurred because people entered a treatment room from the outside to have their issues addressed, not worrying about the consequences their interrupting actions may have on the ongoing treatment.

Nearly 30% (58/194) of these interruptions involved the provider providing information to others, 15% (30/194) receiving information, 25% (48/194) involved a task request, and 15% (30/194) required the dentist to authorize / sign a document. The remaining 15% (28/194) fell in other categories (mainly technical issues). Over 20% (40/194) of observed interruptions occurred during critical tasks. Overall, 30% (59/194) of interruptions caused the providers / assistants to relocate.



On average, providers were interrupted every 31 minutes (i.e., ~2 interruptions per hour). Distributed according to the daily workload, most interruptions occurred while more providers were working simultaneously and during normal office hours (Figure 3.7). This was expected, as the higher patient throughput and larger number of providers working at the same time should result in more interactions between staff members as well as more external interactions.

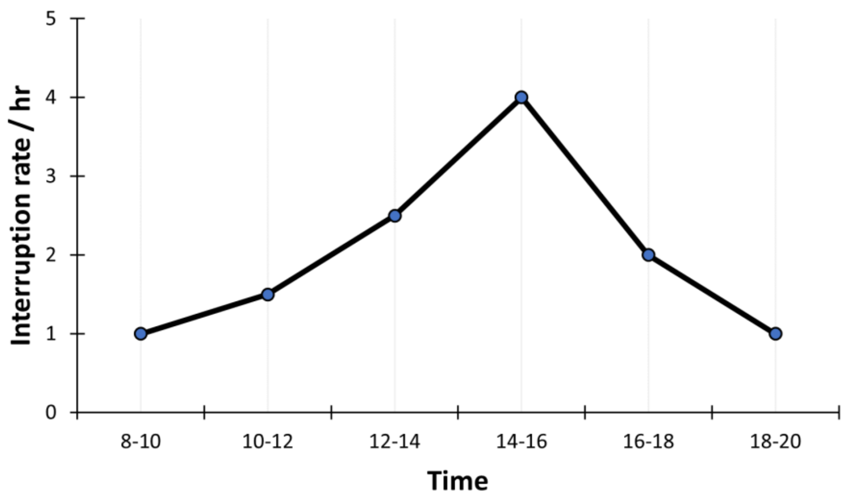


Figure 3.7: Interruption rate

The duration of the observed interruptions varied greatly; either they were rather short (23% were under 1 minute) and consisted of a brief verbal exchange of information or tended to be time consuming (39% took longer than 10 minutes to resolve). These usually either involved a provider having to work on someone or something else in between, doing some rework because of the interruption, or technical issues (Figure 3.8)

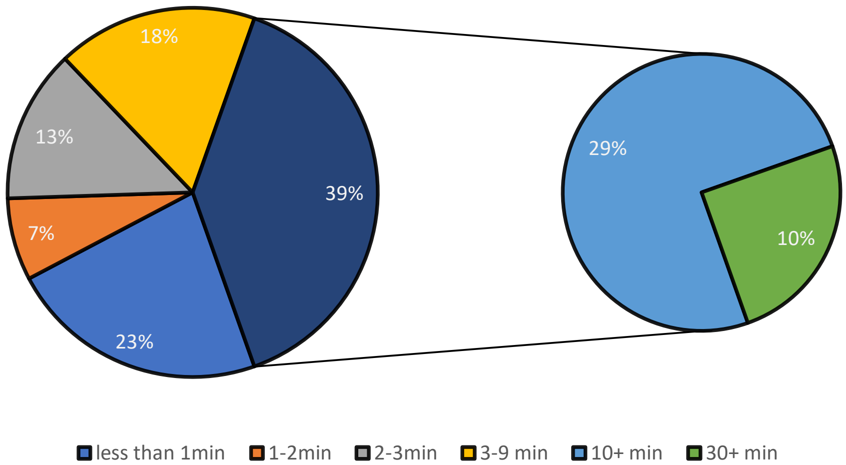


Figure 3.8: Duration of Interruptions

In terms of provider satisfaction survey, while 83% of the providers agreed that interruptions lead to noticeable time losses / increased wait times, none supported the idea that all interruptions should be eliminated. All providers agreed that interruptions should be eliminated during pre-defined critical procedures (such as work close to apex, bonding and adhesive steps to name a few). Further, everyone agreed or strongly agreed that interruptions have a negative impact on their work satisfaction (Table 3.2).

Table 3.2: Provider survey related to interruptions they experienced

Interruptions experienced while working on your patients ...	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
… add to your daily workload			2	2	2
… lead to noticeable time loss / increased wait				5	1
… have negative impact on your work satisfaction				3	3
… could place your patients at risk				5	1
… are sometimes beneficial		1	4	1	
… cause you additional (negative) stress				4	2
… should be eliminated during critical procedures					6
… should ALL be eliminated	1	5			

Techniques to manage interruptions included waiting to turn toward an interrupting person until they were finished with the current task or taking notice of an interrupting person but asking them to wait for a few moments or to leave documents behind on a desk to be dealt with later.

Post-intervention period: During this period, a total of 53 interruptions were observed over another 100 hours of data collection. The clinic used the ‘do not enter’ signs to protect providers from interruptions during this period.

Figure 3.9 shows a summary of observations by source of interruption. Most of the remaining interruptions (about 45%; 24 out of 53) occurred because the dental assistants working on the patient made mistakes or did not properly prepare their work. This was followed by technical malfunctions, which remained unchanged compared to the initial observation.

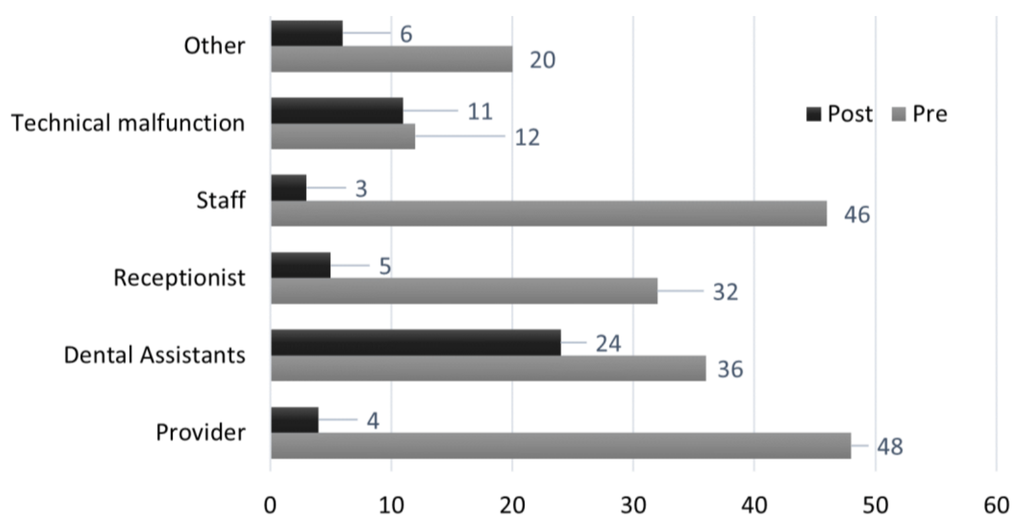


Figure 3.9: Interruptions by source

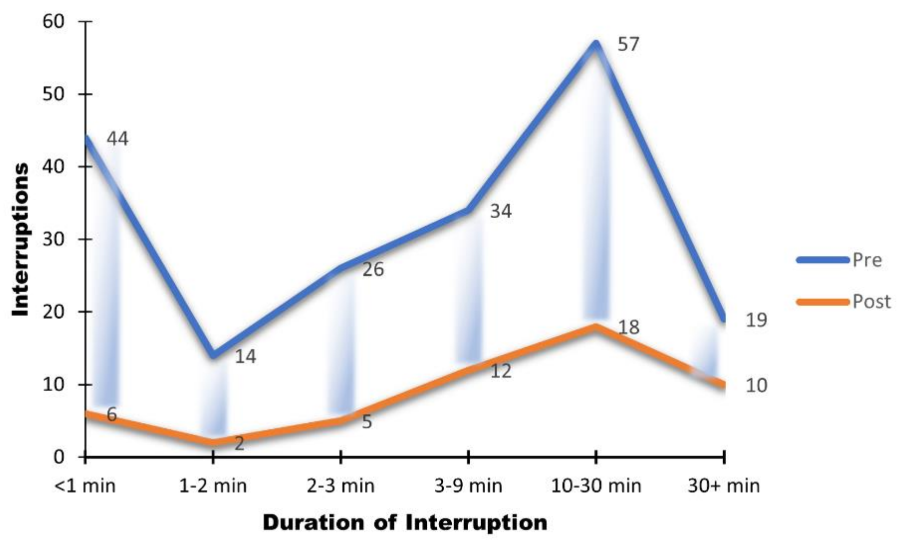


Figure 3.10: Reduced Duration of Interruptions

The duration of the observed interruptions was significantly reduced as well. Figure 3.10 shows a comparison between the observation before and after the intervention. For instance, shorter interruptions (<1 min) reduced from 44 to 6 (86% reduction) while longer interruptions (10 minutes and over) reduced from 76 (57+19) to 28 (18+10), a 63 % reduction. The number of interruptions for a given duration observed during post-intervention were significantly smaller than those observed during pre-intervention (p=0.015; Wilcoxson Signed Rank Test).

Related to the satisfaction survey, Table 3.3 summarizes the providers' responses to the post intervention survey and compares them to the initial responses before they were given the ability to choose when not to be interrupted from the outside.

Table 3.3 Providers' responses on their experiences with interruptions while working on their patients before and after the intervention on a Likert scale; 1 – strongly disagree to 5 – strongly agree

		Average Response		
Question		**Pre**	**Post**	**Improvement**
Interruptions experienced while working on your patients ...				
	...add to your daily workload	4.0	3.0	Yes
	... lead to noticeable time loss / increased wait	4.2	2.5	Yes
	... have negative impact on your work satisfaction.	4.5	2.8	Yes
	... could place your patients at risk	4.2	2.7	Yes
	...cause you additional (negative) stress.	4.3	2.8	Yes
	...should be eliminated during critical procedures	5.0	2.7	Yes

After the intervention, providers experienced interruptions as less of a burden to their daily workload, did not feel they led to as much time loss, had less negative impact on their work satisfaction, and caused less negative stress. These results are also reflected in Table 3.4 where an improvement of the providers' work satisfaction was observed, together with a perception of better work quality and patient safety.

Table 3.4 Providers' self-assessment of different aspects of their work quality on a Likert scale: 1 – strongly disagree to 5 – strongly agree

Post intervention...			
	... the work environment improved patient safety	4.0	Yes
	... the quality of my work improved	4.0	Yes
	... the perceived time lost decreased	4.5	Yes
	... I felt less stressed	4.3	Yes
	...my overall work satisfaction improved	4.7	Yes

To ensure the intervention did not create unanticipated problems itself, questions were asked relating to the usability and user experience of the intervention (see Table 3.5). Across all questions, the providers responded as having a positive impact on their workflow with minimal interruptions.

Table 3.5 Providers’ opinions about using the intervention in their daily work on a Likert scale; 1 – strongly disagree to 5 – strongly agree

Using the intervention…			
	… I experienced problems operating the sign	1.0	positive
	… I used the sign during critical procedures	4.5	positive
	… the extra steps added noticeable workload	2.0	positive
	… caused new interruptions that wouldn't have occurred	1.0	positive
	…helped mitigate / eliminate the effects of the most		
	prevalent interruptions in the daily work	4.7	positive
	...eliminated interruptions during critical procedures	4.2	positive

3.4 Discussion

To our knowledge, this study was the first to evaluate interruptions in a dental setting, along with an implementation of an intervention. Quantitative data collected from observations suggested that the observed interruptions tend to break the delivery of steady treatment. Further, a satisfaction survey from the providers suggested their work satisfaction degenerated due to frequent interruptions, which required them to refocus, caused them stress and increased the risk of having to do rework. A simple, yet easy-to-understand, and sustainable intervention such as the ‘Do not enter’ sign used in our study can drastically reduce unwanted interruptions and improve provider satisfaction, potentially leading to improved dental care.

Several studies have focused on the rate of interruptions and their effects. In a German hospital emergency department, Weigl et al. (2017) noted 7.5 interruptions per hour, while it was 5.3 interruptions per hour in an internal medicine and surgery ward of a German hospital (Weigl et al. 2010). For a U.S. hospital ICU, approximately 3 interruptions per hour were observed (Ballermann MA et al., 2011; Craker et al., 2017). In our study, we found interruptions at our dental clinic to occur twice per hour, which, although smaller than the other settings, was still perceived as bothersome by the affected dental providers. While many interruptions were <1 min (23%), a small number of them (10%) were rather long (>30 min). A short interruption period did not guarantee that no mistake was made, but none was noticed at the time and the procedure restarted quickly. But in case of a long interruption that was caused due to an error, depending on the treatment performed and the process step it was in, it could lead to time loss due to rework of 30 minutes and more. Examples of this included an inlay or crown improperly attached, a tooth broke during the insertion, and adhesive not properly cured.

When it comes to interruption sources, they vary among the various specialties based on specific characteristics of those specialties (Schneider A, Williams DJ et al. 2020; Zhu et al 2020; Lee T, Rosario H et al. 2021). A recent study at French hospital units summarized various interrupters from the point of view of work functions involved (Teigne´ D, Cazet L et al. 2023). Unlike what some studies in the hospital nursing environment suggested (Relihan 2010, Kreckler S et al 2008, Pape T 2003), the majority (75%; 145/194) of the interruptions we observed in the dental clinic were not self-induced by the staff members, but these interruptions occurred due to sources who entered the treatment rooms from the outside as indicated in Figure 6. This corroborates with previous studies, which also suggested that other health care team members are the largest source of interruptions (McGillis Hall L et al. 2010; Craig J, 2014; Blocker RC, Heaton HA, Forsyth KL et al. 2017; Weigl, Catchpole 2020). Family members were not a source of interruptions during treatment as they were generally not allowed to be in the treatment room at our dental clinic. In our setting, we further noticed that most interruptions sources did not have the urgency to justify an immediate interruption to a treatment process. Upon deeper look at the sources of interruptions, we noticed that many of them were related to paperwork or requests for information or obtaining supplies or equipment, all of which could have waited a few minutes to avoid interrupting a critical task.

Interruptions can also have detrimental effects on job satisfaction, workflow efficiency and patient safety. They were an important factor in the medical providers' workload and could result in medication as well as other errors (Bell 2018, Weigl et al. 2012, Weigl et al. 2014, Li et al. 2012, Zhu 2022). Our survey also found that interruptions add to the providers' daily workload and cause them additional stress, as highlighted with scores of 4.0 and 4.3 out of 5 in Table 3. Clearly, dental providers need to have a sharp focus on a variety of complex and potentially harmful (to the patient) tasks. Any interruption that breaks this focus not only adds workload and stress due to the additional work to be performed, but also adds stress as the providers need to refocus, knowing that the likelihood of making an error has just been increased due to the fact their original procedure had been interrupted. Delay in refocusing on the primary task and potential errors have also been observed in lab studies and a study with emergency physicians (Bailey and Konstan, 2006, Westbrook et al., 2018)

The satisfaction survey data further confirmed that dental provider satisfaction degraded with interruptions, especially if they were involved in critical processes and/or result in lengthy rework procedures. This is again indicated in Table 3.3 by an average response of 4.5 on a Likert scale, agreeing that interruptions had a negative impact on work satisfaction. As staff turnover presents a serious challenge to health care (Karlsson AC, Gunningberg L 2019), work satisfaction is an essential factor in medical staff retention.

From an intervention standpoint, based on whether or not the intervention is attached to the provider or otherwise moved together with them throughout their work environment, we can categorize them as ‘dynamic’ or ‘static’ interventions. Examples of ‘dynamic’ interventions include drug round tabards (Verweij L et al. 2014), vests (Craig J, 2014), and red disposable aprons (Relihan, 2010). However, due to the ‘static’ nature of the services provided in a dental treatment, our intervention of ‘Do not enter’ light was selected. We created a static, protective bubble around the treatment area, which blocked the dynamics of the outside world during critical phases of the treatment. Having an item attached to a dental provider would not have been a suitable solution as it would not have been noticeable before someone opened the door to the treatment room, which by itself has the potential to cause an interruption.

The general impact of our intervention was the creation of a quieter and, thus, a more structured treatment environment. Our survey data showed that our intervention helped mitigate the effects of the most prevalent interruptions in the providers’ daily work (strong agreement of 4.7 on Likert scale – Table 3.5). This corroborates with findings from previous research that had led to the ‘sterile cockpit’ in the aviation industry, which allows pilots to perform their tasks without interruptions during defined critical periods, leading to a lower risk of errors (Dismukes K, Young G, Sumwalt R 1998; Pape T 2003). Our data showed a fairly strong (4.2 on Likert scale) elimination of interruptions during critical procedures (Table 3.5). This approach has seen some critique for the hospital environment, as some studies identified certain beneficial interruptions, which would inadvertently be excluded by the ‘sterile cockpit’ approach. For the dental clinic, our observations and survey data did not identify any benefit from interruptions.

We were able to achieve a reduction in short interruptions (<1min) of 86% and 63% for longer interruptions (>10 min), with most providers adhering to the proper use of the sign and staff members observing it. We reduced the number of ‘avoidable’ interruptions (those that could potentially be eliminated by the intervention) by 87.5%, from 146 to 18 interruptions over the 100 hr observation period (Figures 9 and 10). This differs from findings of Federwisch M et al. (2014) who determined one of the reasons for failure of their intervention of a sterile cockpit approach to be lack of compliance. The ease of use and the convincing results from our study can make our intervention a sustainable, long-term solution.

Our survey data also confirmed a previous study by Bell et al. (2018), which showed that medical staff in general feel that reducing interruptions improves patient safety, workload, accuracy, job satisfaction and mental health. We discovered in our case, that providers found their modified work environment improved patient safety and the quality of their work (both 4.0 on Likert scale, Table 3.4), resulting in a strong improvement of the overall work satisfaction (4.67 on the Likert scale, Table 3.5).

Retaining qualified staff members is critical today, as finding a suitable replacement can take weeks or months, thus costing tens of thousands of dollars and endangering patient satisfaction should they not be treated in a timely fashion due to staff shortage. While at our practice, we already had a system that needed modification to convert it to a ‘Do not enter’ sign, a $1,000 per room cost to set up such a sign with a remote appears quite reasonable compared to the loss in revenue to the clinic, and patient satisfaction and eventual loyalty.

There are, however, limitations of this study. First, the sample size was small (6 providers) and was performed within a mid-size German practice. Hence, our findings may not be generalizable to other practices of different sizes or locations, as their system of care, layout, and staffing pattern may be different, and cultural factors might affect the impact of the interventions in other countries/settings as well. However, our study does provide, for the first time in academic literature, a fundamental understanding of interruptions in a dental practice, with a possible easy-to-implement and sustain intervention. Our approach can be used (with appropriate modifications) for other practices to evaluate interruptions and test the intervention we have proposed.

Second, the pre-post nature of the study, unlike a randomized controlled trial, could have allowed confounding factors to positively or negatively impact our findings. However, utmost care was taken by the lead author to ensure no other parallel process improvement efforts were in place or any other procedural changes occurred during the pre- and post-periods.

Third, analysis of the case mix of patients and how it varied from pre to post study were not considered. Patient case mix may influence the number and nature of interruptions in multiple ways; e.g., length of treatment or the requirement for authorization on documents for other patients. However, given the sufficiently long period of data collection

(100+ hours during pre- and post-periods), variations in the daily case mix would have averaged out. Finally, it is unknown to what extent the observer influenced the behavior of staff during the assessment. Efforts were made to limit the Hawthorne effect by the observer maintaining a distance from the dental unit/treatment area, adopting a discreet observation behavior and not engaging in conversation with staff.

Further research could extend our work to include a timer that would allow for the interrupting provider to see the remaining time on the 'Do not enter' sign and return at a later time. This could help improve overall efficiency, as the person wanting to enter may decide to either wait in front of the door a short period of time or choose to continue on other tasks and return later. Replicating this study at other dental clinics, of different sizes and in different countries, would help generalize findings from our study.

CHAPTER 4

CONCLUSIONS

Interruptions during dental treatments are frequent and have a negative impact on provider performance and satisfaction. Interruptions also increase the risk for treatment errors. While interruptions in many other medical environments (mainly hospitals) have been studied, there was no literature that covered research on interruptions in the dental environment. Also, there was a lack of a framework to guide us in studying these interruptions and to design and successfully implement a suitable intervention. This led us to investigate this challenge and make two key contributions through this dissertation.

4.1 Summary of Contribution 1

The DSIR framework proposed in our work can inform research that aims to design interventions using design science research prospectively and iteratively, with the intent to implement the outcome in a practical healthcare application.

The framework is composed of four interrelated stages. The Environment stage covers the healthcare facility including its providers and resources as they are facing interruptions. The Knowledge Base enables understanding of existing literature on interruptions as well as expert opinions of the affected providers and allows for adding new knowledge based on findings from the study. Design and Development is the core stage in finding and proposing a suitable intervention. Finally, the Implementation stage ensures sufficient (monetary) resources to purchase, build and install the necessary equipment and supports the implementation process from start to finish.

Each of the stages is connected to its neighbors, via cycles promoting refinement and adaptation. The Relevance and Rigor cycles ensure that studies are not performed in a 'vacuum.' The Relevance cycle enables and reminds the researcher to observe and interact with the physical environment of the healthcare facility the research is supposed to apply to. The Rigor cycle helps consider existing literature about interventions to reduce interruptions and other factual data to better understand the success factors and limitations others have previously determined in similar situations. The Design-Implementation cycle covers the work involved in iteratively designing an intervention with its implementation in mind, making adjustments and corrections based on provider feedback along the way. Necessary process changes and required staff training resulting from the intervention are handled in the Change Management cycle. A Sustainability cycle is included to ensure the implementation of the intervention matches the needs and expectations at the healthcare facility to maintain a long-term success.

A key finding of this research was that following only the cycles of DSR may result in an artifact that is difficult to sustainably implement. Adding the foresighted approach of implementation research could help rolling out new procedures enabling a successful deployment of the artifact.

Essentially, our proposed DSIR framework, with its focus on the iterative design, development and implementation of a research artifact, underscores a commitment to improvements in both the efficacy and quality of professional practice.

4.2 Summary of Contribution 2

We conducted a pilot study as a practical application for the DSIR framework. The Environment stage helped select the 6 dental providers (3 dentists and 3 hygienists) and assisted in considering the relevant procedures. Our ideas went through a Relevance cycle, where we reviewed literature and discussed with the dental providers to make sure the project was indeed relevant to all involved. We created the design of the study and our forms and surveys with the help of literature during the Knowledge Base stage, before we collected baseline data of 100 working hours spread over a 5-month period. This was followed by a Rigor cycle to compare our first results against the extensive studies about interruptions and work satisfaction.

The Design and Development stage guided us through the design and initial testing steps with provider feedback in Design-Implementation Cycles towards piloting our remote-controlled sign. This made sure we accounted for a hygienic and comfortable remote-control solution that was acceptable for all providers. Before moving forward, another Rigor cycle made sure the intervention was suitable for the task.

Finally, the Implementation stage, initiated with the investment in additional equipment and a rollout of the remote-controlled system into all treatment rooms, accompanied by the necessary change management steps as part of the Change Management Cycle, such as re-defining some processes and the resulting staff training. We observed another 100 working hours over a 2-month period, surveyed the providers and found a significant reduction in interruptions that lead to a general improvement of provider satisfaction without increasing the providers' workload. This stage ended with a last Rigor cycle – the compilation and publication of a paper that summarized our findings as a way to enhance and expand the knowledge base with our findings for future research. The long-term availability is supported by the Sustainability Cycle to make future adjustments to suit changes in the environment. Newer government policies made it necessary to revise the installation, which led to difficulties in sustaining the implementation.

Among several initial options that were discussed based on literature review, the switchable ‘Do Not Enter’ sign was chosen, because it appeared to be the most appropriate solution. Any intervention attached to a provider (like a vest, tabard etc.) would have been noticed too late – that is after at least a distraction would have happened by opening the door. To be successful, the intervention had to ‘work’ before someone chose to open a door to one of the treatment rooms, while at the same time it should not cause any significant extra work to the providers (such as having to get up and walk to a light switch etc.) – which would have resulted in the intervention itself becoming o new source for interruption to the treatment procedures.

This study demonstrated that a switchable sign can substantially reduce the number of interruptions in a dental clinic; the total number of interruptions dropped by 72.5% with short interruptions (<1min) by 86%. It also showed the potential of improving the work environment and increasing provider satisfaction (average response: 4.7 on a 1-5 Likert scale) by reducing interruptions to the dental providers. The providers also felt less stressed (4.3 on a 1-5 Likert scale). The impact on this specific clinic’s workflow could be seen in improved procedure times, less stress due to significantly less unexpected and unpredictable ‘extra work,’ that lowered the risk of having to cancel a patient during a workday or to end up in overtime. The nature of the scheduling approach of the clinic (no walk-ins) somewhat prohibits an increase in patient throughput beyond the scheduled treatments.

Surveys with clinic staff were conducted to gather subjective feedback on the sign's influence on their experience. All providers saw a change in their work environment, especially less stress which led to a higher reported work satisfaction. At the same time the ease of use and perceived integration of the artifact into the existing workflows was evaluated with further qualitative questions.

Applying the new DSIR framework helped create a successful new approach towards dealing with interruptions in a dental / healthcare setting and had a great positive impact on the daily operation of this dental clinic.

4.3 Future Work

We believe that our proposed DSIR framework's proven success in helping understand interruptions and reducing interruptions at this single site dental clinic has the potential to justify further research in this area to generalize our findings. This can be done by employing DSIR for interruption study and intervention design and implementation at other practices of different sizes or at different locations. Differences in their systems of care, layout, and staffing pattern, along with cultural factors, might affect the impact of the interventions at those locations. Steps to generalize these findings could initially be conducted through further studies in other German clinics (with a similar socio-economic and regulatory environment) and generally anywhere a setting is similar in the way that a medical treatment is performed in an enclosed environment (e.g., room with door(s)) and where the providers only benefits from a ‘sterile cockpit’ approach during intermittent phases, while an interruption could be acceptable or even beneficial at other times.

As a further extension one could try to employ this idea to other settings – like nurses’ medication runs – by creating a battery operated ‘display’ of some kind to analyze if a switchable and possibly flashing or otherwise extremely visible solution has a different outcome compared to previous studies that involved vests and tabards that were permanently worn and did not stand out with electronic visual effects.

Considering the lessons learned during the implementation of the intervention, several suggestions are made for future studies. First, researchers should make sure everyone, not only the immediate stakeholders - is ‘on board’ and understands what is expected from them, to avoid complications or bias from people who did not know better. Second, it is also advisable to not simply purchase or create items with the researcher’s background and view in mind, but to test the useability of any device that needs physical interaction with all participants to make sure they can and are willing to operate it properly. Where alternatives are available, offer and test multiple options for better compliance.

Third, not to start a pilot study without interacting with the participants that will generate the data to avoid being sabotaged or risk facing other forms of ‘hesitation’ towards proper use of an intervention, that could create inconsistent data. Finally, remove any obstacle that can be anticipated before starting any data collection. This helps avoid being confronted with problems half-way through the data collection, at the risk of having to start over after correcting the problem to then finally collect accurate data.

REFERENCES

1. Anderson, J. G., & Abrahamson, K. (2017). Your health care may kill you: Medical errors. ITCH, 234, 13-17.
2. Bagni, G., Godinho Filho, M., Finne, M., & Thürer, M. (2024). Design science research in operations management: is there a single type?. Production Planning & Control, 1-19.
3. Bailey, B. P., & Konstan, J. A. (2006). On the need for attention-aware systems: Measuring effects of interruption on task performance, error rate, and affective state. Computers in Human Behavior, 22(4), 685-708.
4. Ballermann, M. A., Shaw, N. T., Mayes, D. C., Gibney, R. N., & Westbrook, J. I. (2011). Validation of the Work Observation Method By Activity Timing (WOMBAT) method of conducting time-motion observations in critical care settings: an observational study. BMC Medical Informatics and Decision Making, 11, 1-12.
5. Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Rossi, M. (2018). Design science research contributions: Finding a balance between artifact and theory. Journal of the Association for Information Systems, 19(5), 3.
6. Bauer, M. S., Damschroder, L., Hagedorn, H., Smith, J., & Kilbourne, A. M. (2015). An introduction to implementation science for the non-specialist. BMC Psychology, 3, 1-12.
7. Bauer, M. S., & Kirchner, J. (2020). Implementation science: What is it and why

should I care?. Psychiatry Research, 283, 112376.

8. Beer, M. (2003). Why total quality management programs do not persist: the role of management quality and implications for leading a TQM transformation. Decision Sciences, 34(4), 623-642.
9. Bell, L. T. O., James, R., Rosa, J. A., Pollentine, A., Pettet, G., & McCoubrie, P. (2018). Reducing interruptions during duty radiology shifts, assessment of its benefits and review of factors affecting the radiology working environment. Clinical Radiology, 73(8), 759-e19.
10. Blocker, R. C., Heaton, H. A., Forsyth, K. L., Hawthorne, H. J., El-Sherif, N., Bellolio, M. F., ... & Hallbeck, M. S. (2017). Physician, interrupted: workflow interruptions and patient care in the emergency department. The Journal of Emergency Medicine, 53(6), 798-804.
11. Brixey, J. J., Robinson, D. J., Johnson, C. W., Johnson, T. R., Turley, J. P., Patel, V. L., & Zhang, J. (2007). Towards a hybrid method to categorize interruptions and activities in healthcare. International Journal of Medical Informatics, 76(11-12), 812-820.
12. Brixey, J. J., Tang, Z., Robinson, D. J., Johnson, C. W., Johnson, T. R., Turley, J. P., ... & Zhang, J. (2008). Interruptions in a level one trauma center: a case study. International Journal of Medical Informatics, 77(4), 235-241.
13. Burnes, B. (2004). Emergent change and planned change–competitors or allies? The case of XYZ construction. International Journal of Operations & Production Management, 24(9), 886-902.
14. Craig, J., Clanton, F., & Demeter, M. (2014). Reducing interruptions during

medication administration: the White Vest study. Journal of Research in Nursing, 19(3), 248-261.

15. Craker, N. C., Myers, R. A., Eid, J., Parikh, P., McCarthy, M. C., Zink, K., & Parikh, P. J. (2017). Nursing interruptions in a trauma intensive care unit: a prospective observational study. JONA: The Journal of Nursing Administration, 47(4), 205-211.
16. Damschroder, L. J., Aron, D. C., Keith, R. E., Kirsh, S. R., Alexander, J. A., & Lowery, J. C. (2009). Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implementation Science, 4, 1-15.
17. Damschroder, L. J., Reardon, C. M., Widerquist, M. A. O., & Lowery, J. (2022). The updated Consolidated Framework for Implementation Research based on user feedback. Implementation Science, 17(1), 75.
18. Denyer, D., Tranfield, D., & Van Aken, J. E. (2008). Developing design propositions through research synthesis. Organization Studies, 29(3), 393-413.
19. Devaraj, S., Ow, T. T., & Kohli, R. (2013). Examining the impact of information technology and patient flow on healthcare performance: A Theory of Swift and Even Flow (TSEF) perspective. Journal of Operations Management, 31(4), 181-192.
20. Dismukes, R. K., Young, G. E., Sumwalt III, R. L., & Null, C. H. (1998, January). Cockpit interruptions and distractions: Effective management requires a careful balancing act. In CRM Industry Conference.
21. Federwisch, M., Ramos, H., & Shonte'C, A. (2014). The sterile cockpit: an effective approach to reducing medication errors?. AJN The American Journal of Nursing, 114(2), 47-55.

22. Feldstein, A. C., & Glasgow, R. E. (2008). A practical, robust implementation and sustainability model (PRISM) for integrating research findings into practice. The Joint Commission Journal on Quality and Patient Safety, 34(4), 228-243.

23. Fixsen, D. L., Naoom, S. F., & Blase, K. a, Friedman, RM, & Wallace, F.(2005). Implementation research: A synthesis of the literature. National Implementation Research Network (Ed.), Components, 311712.

24. Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: systematic review and recommendations. The Milbank Quarterly, 82(4), 581-629.

25. Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. MIS Quarterly, 337-355.

26. Gustafson, D. H., Sainfort, F., Eichler, M., Adams, L., Bisognano, M., & Steudel, H. (2003). Developing and testing a model to predict outcomes of organizational change. Health Services Research, 38(2), 751-776.

27. Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. MIS quarterly, 75-105.

28. Hevner, A. R. (2007). A three cycle view of design science research. Scandinavian Journal of Information Systems, 19(2), 4.

29. Hevner, A., & Chatterjee, S. (2010). Design research in information systems: theory and practice (Vol. 22). Springer Science & Business Media.

30. Holmström, J., Ketokivi, M., & Hameri, A. P. (2009). Bridging practice and theory: A design science approach. Decision Sciences, 40(1), 65-87.

31. James, J. T. (2013). A new, evidence-based estimate of patient harms associated with

hospital care. Journal of Patient Safety, 9(3), 122-128.

32. Johnson, M., Burgess, N., & Sethi, S. (2020). Temporal pacing of outcomes for improving patient flow: Design science research in a National Health Service hospital. Journal of Operations Management, 66(1-2), 35-53.
33. Jones, D., & Gregor, S. (2007). The anatomy of a design theory. Journal of the Association for Information Systems, 8(5), 1.
34. Karlsson, A. C., Gunningberg, L., Bäckström, J., & Pöder, U. (2019). Registered nurses' perspectives of work satisfaction, patient safety and intention to stay–A double-edged sword. Journal of Nursing Management, 27(7), 1359-1365.
35. Kaplan, R. S. (1998). Innovation action research: creating new management theory and practice. Journal of Management Accounting Research, 10, 89.
36. Klaic, M., Kapp, S., Hudson, P., Chapman, W., Denehy, L., Story, D., & Francis, J. J. (2022). Implementability of healthcare interventions: an overview of reviews and development of a conceptual framework. Implementation Science, 17(1), 10.
37. Klein, K. J., & Sorra, J. S. (1996). The challenge of innovation implementation. Academy of Management Review, 21(4), 1055-1080.
38. Kreckler, S., Catchpole, K., Bottomley, M., Handa, A., & McCulloch, P. (2008). Interruptions during drug rounds: an observational study. British Journal of Nursing, 17(21), 1326-1330.
39. Kuechler, W., & Vaishnavi, V. (2012). A framework for theory development in design science research: multiple perspectives. Journal of the Association for Information Systems, 13(6), 3.
40. KZBV - Kassenzahnärztliche Bundesvereinigung KdöR - Jahrbuch 2021 –

Statistische Basisdaten zur vertragszahnärztlichen Versorgung, 2021

41. Lee, T., Rosario, H., Cifuentes, E., Cui, J., Lin, E. C., Miller, V. A., & Lin, H. C. (2021). Review of interruptions in a pediatric subspecialty outpatient clinic. PLOS one, 16(7), e0254528.
42. Li, S. Y., Magrabi, F., & Coiera, E. (2012). A systematic review of the psychological literature on interruption and its patient safety implications. Journal of the American Medical Informatics Association, 19(1), 6-12.
43. Makary, M. A., & Daniel, M. (2016). Medical error—the third leading cause of death in the US. BMI, 353.
44. March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. Decision Support Systems, 15(4), 251-266.
45. McAlearney, A. S., Walker, D. M., Livaudais-Toman, J., Parides, M., & Bickell, N. A. (2016). Challenges of implementation and implementation research: Learning from an intervention study designed to improve tumor registry reporting. SAGE open medicine, 4, 2050312116666215.
46. McGillis Hall, L. M., Pedersen, C., Hubley, P., Ptack, E., Hemingway, A., Watson, C., & Keatings, M. (2010). Interruptions and pediatric patient safety. Journal of Pediatric Nursing, 25(3), 167-175.
47. MDK – Medizinischer Dienst der Krankenversicherung – Jahresstatistik 2019 – Behandlungsfehler-Begutachtung der MDK-Gemeinschaft, MDS e.V. 2020
48. Myers, R. A., & Parikh, P. J. (2019). Nurses' work with interruptions: an objective model for testing interventions. Health Care Management Science, 22, 1-15.
49. Nurumal, M., Makabe, S., Che Jamaludin, F. I., Fahmi Mohd Yusof, H., Aung, K. T.,

& Kowitlawakul, Y. (2017). Work-life balance among teaching hospital nurses in Malaysia. Global Journal of Health Science, 9(9), 81.

50. Omachonu, V. K., & Einspruch, N. G. (2010). Innovation in healthcare delivery systems: a conceptual framework. The Innovation Journal: The Public Sector Innovation Journal, 15(1), 1-20.
51. Pape, T. M. (2003). Applying airline safety practices to medication administration. Medsurg Nursing, 12(2).
52. Parikh, P. J., Craker, N., Myers, R. A., Eid, J. M., Parikh, P., Zink, K., & McCarthy, M. C. (2016). The Anatomy of Nursing Interruptions: Who-What-When-Where. 29th Annual Scientific Assembly – Scientific Posters, 18,35-36. https://corescholar.libraries.wright.edu/surg/685
53. Patrício, L., Grenha Teixeira, J., & Vink, J. (2019). A service design approach to healthcare innovation: From decision-making to sense-making and institutional change. AMS Review, 9, 115-120.
54. Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of Management Information Systems, 24(3), 45-77.
55. Ratwani, R., Hettinger, Z., Brixey, J., Rivera, A. J., & Colligan, L. (2014, September). Managing interruptions in healthcare: from theory to practice. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 58, No. 1, pp. 624-628). Sage CA: Los Angeles, CA: SAGE Publications.
56. Relihan, E., O'Brien, V., O'Hara, S., & Silke, B. (2010). The impact of a set of interventions to reduce interruptions and distractions to nurses during medication

administration. Quality and Safety in Health Care, 19(5), e52-e52.

57. Rogers, E. M., & Cartano, D. G. (1962). Methods of measuring opinion leadership. Public Opinion Quarterly, 435-441.

58. Schmenner, R. W. (2015). The pursuit of productivity. Production and Operations Management, 24(2), 341-350.

59. Schneider, A., Williams, D. J., Kalynych, C., Wehler, M., & Weigl, M. (2021). Physicians' and nurses' work time allocation and workflow interruptions in emergency departments: a comparative time-motion study across two countries. Emergency Medicine Journal, 38(4), 263-268.

60. Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. MIS Quarterly, 37-56.

61. Simon, H. A. (1996). The Sciences of the Artificial (3rd ed) Cambridge MA: MIT Press

62. Simon, H. A. (2002). Forecasting the future or shaping it?. Industrial and Corporate Change, 11(3), 601-605.

63. Stetler, C. B., Legro, M. W., Wallace, C. M., Bowman, C., Guihan, M., Hagedorn, H., ... & Smith, J. L. (2006). The role of formative evaluation in implementation research and the QUERI experience. Journal of General Internal Medicine, 21(Suppl 2), S1-S8.

64. Teigné, D., Cazet, L., Mabileau, G., & Terrien, N. (2023). Task interruptions from the perspective of work functions: The development of an observational tool applied to inpatient hospital care in France The Team'IT tool. PLOS one, 18(3), e0282721.

65. Teixeira, J. G., Patrício, L., & Tuunanen, T. (2019). Advancing service design

research with design science research. Journal of Service Management, 30(5), 577-592.

66. Van Aken, J. E. (2004). Management research based on the paradigm of the design sciences: the quest for field-tested and grounded technological rules. Journal of Management Studies, 41(2), 219-246.
67. Van Aken, J., Chandrasekaran, A., & Halman, J. (2016). Conducting and publishing design science research: Inaugural essay of the design science department of the Journal of Operations Management. Journal of Operations Management, 47, 1-8.
68. Verweij, L., Smeulers, M., Maaskant, J. M., & Vermeulen, H. (2014). Quiet please! Drug round tabards: are they effective and accepted? A mixed method study. Journal of Nursing Scholarship, 46(5), 340-348.
69. Weigl, M., Beck, J., Wehler, M., & Schneider, A. (2017). Workflow interruptions and stress at work: A mixed-methods study among physicians and nurses of a multidisciplinary emergency department. BMJ Open, 7(12), e019074.
70. Weigl, M., Catchpole, K., Wehler, M., & Schneider, A. (2020). Workflow disruptions and provider situation awareness in acute care: An observational study with emergency department physicians and nurses. Applied Ergonomics, 88, 103155.
71. Weigl, M., Müller, A., Angerer, P., & Hoffmann, F. (2014). Workflow interruptions and mental workload in hospital pediatricians: an observational study. BMC Health Services Research, 14, 1-7.
72. Weigl, M., Müller, A., Vincent, C., Angerer, P., & Sevdalis, N. (2012). The association of workflow interruptions and hospital doctors' workload: a prospective observational study. BMJ Quality & Safety, 21(5), 399-407.

73. Weigl, M., Müller, A., Zupanc, A., Glaser, J., & Angerer, P. (2011). Hospital doctors' workflow interruptions and activities: an observation study. BMJ Quality & Safety, 20(6), 491-497.

74. Westbrook, J. I., Raban, M. Z., Walter, S. R., & Douglas, H. (2018). Task errors by emergency physicians are associated with interruptions, multitasking, fatigue and working memory capacity: a prospective, direct observation study. BMJ Quality & Safety, 27(8), 655-663.

75. Zhu, X., Hu, Y., Wang, L., Li, D., & Wu, X. (2022). An Observational Study of Physicians' Workflow Interruptions in Outpatient Departments in China. Frontiers in Public Health, 10, 884764.

Appendix A: Data Collection Form

Staff members:			Patient:	
Times (hh:mm:ss)	Location of interruption	Task interrupted	Source of interruption (Initiator)	Medium of interruption
Interruption	□ Treatment room	□ P treat screening	□ Patient (own)	□ Face-to-face
Start : :		□ P treat filling	□ Patient (other)	□ phone
End : :		□ P treat CEREC	□ Family	□ message on computer
Original task	□ Lab (CEREC)	□ X-Ray	□ Dentist	□
Return : :		□ Documentation	□ Hygienist	□ other
		□ Communication	□ Dental Assistant	
		□ Scheduling	□ Receptionist	
Multitasking ? □		□ primary	□ Sales Rep	
		□ secondary	□ tech failure	
interruption description:			□ other	
□ Task	□ Receive Info		signal?	Staff affected (Recipient)
□ ChgTask	□ Provide Info	□ Relocate to:		□ Dentist
□ Authorise / sign				□ Dental Assistant
Observed Impact:				□ Hygienist
Observed Intervention:				
Outcome				

Appendix B: Provider Survey (PRE)

SURVEY: Interruptions in a Dental Clinic

PURPOSE OF SURVEY This survey was created by Carsten Ziegler (PhD in Industrial Engineering candidate at University of Louisville) to capture how interruptions are viewed by dentists and hygienists working in a German dental clinic. Your participation in this survey will allow us to better understand the interruptions you experience.

DEFINITION OF INTERRUPTION For this survey, please think of interruptions as anything that takes your attention away from a task or communication activity that you were already engaged in as part of your job.

CONFIDENTIALITY Your response to this survey will be de-identified before being shared. Identifying questions in the final section will be used by investigators during survey administration to make sure we have a good cross section of the dentist / hygienist population.

TIME TO TAKE SURVEY It is estimated that this survey will take 5 minutes to complete. We understand that your time is valuable and appreciate the time and effort you are giving in support of our research. (Check marks√'s, X's, or filling in the spot with ANY color pencil or pen are ALL OK.)

SECTION 1: Please indicate your level of agreement with the following statements...

Q1 Interruptions experienced while working on your patients ...add to your daily workload.

- ❑ **Strongly Disagree**
- ❑ **Disagree**
- ❑ **Neither Agree nor Disagree**
- ❑ **Agree**
- ❑ **Strongly Agree**

Q2 Interruptions experienced while working on your patients … lead to noticeable time loss / increased wait times.

- ❑ **Strongly Disagree**
- ❑ **Disagree**
- ❑ **Neither Agree nor Disagree**
- ❑ **Agree**
- ❑ **Strongly Agree**

Q3 Interruptions experienced while working on your patients … have negative impact on your work satisfaction.

- ❑ **Strongly Disagree**
- ❑ **Disagree**
- ❑ **Neither Agree nor Disagree**
- ❑ **Agree**
- ❑ **Strongly Agree**

Q4 Interruptions experienced while working on your patients … could place your patients at risk.

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q5 Interruptions experienced while working on your patients ...are sometimes beneficial.

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q6 (Optional) Examples of interruptions you've noticed that may be BENEFICIAL TO PATIENTS OR YOU:

____

____

____

Q7 Interruptions experienced while working on your patients ...cause you additional (negative) stress.

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q8 Interruptions experienced while working on your patients ...should be eliminated during critical procedures (e.g. bonding / adhesive steps, root canal filling, work close to apex)

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q9 Interruptions experienced while working on your patients ...should ALL be eliminated.

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

SECTION 2: Please answer the following questions about interruptions you have noticed and WHEN (during which type of treatment) they occur...

Q10 WHEN do interruptions occur most often that … could place your patients at risk? (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q11 WHEN do interruptions occur most often that ...add to your daily workload? (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q12 WHEN do interruptions occur most often that … lead to noticeable time loss / increased wait times (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q13 WHEN do interruptions occur most often that … have negative impact on your work satisfaction? (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q14 WHEN do interruptions occur most often that ...cause you added stress? (Choose up to 3 responses)
Endodontics
X-Ray
Exam / Check-Up
Treatment - Filling
Treatment - CEREC
Treatment - Perio
Other ____________________

Q15 (Optional) Please share anything additional you've noticed about WHEN interruptions occur:

____

____

____

SECTION 3: Please answer the following questions about how often you use the technique stated to MANAGE INTERRUPTIONS you experience...

Q16 Do you use the following to MANAGE INTERRUPTIONS you experience?
"Wait to turn away from patient / toward an interrupting person until finished with current task."
- ❍ **Never**
- ❍ **Rarely**
- ❍ **Sometimes**
- ❍ **Most of the Time**
- ❍ **Always**

Q17 Do you use the following to MANAGE INTERRUPTIONS you experience?
"Take notice of interrupting person, but ask them to wait for a few moments."
- ❍ **Never**
- ❍ **Rarely**
- ❍ **Sometimes**
- ❍ **Most of the Time**
- ❍ **Always**

Q18 Do you use the following to MANAGE INTERRUPTIONS you experience?
"Write note to self as reminder to finish interrupted task."
- ❍ **Never**
- ❍ **Rarely**
- ❍ **Sometimes**
- ❍ **Most of the Time**
- ❍ **Always**

Q19 Do you use the following to MANAGE INTERRUPTIONS you experience?
“Ask someone else to remind you to return to interrupted task.”

- Never
- Rarely
- Sometimes
- Most of the Time
- Always

Q20 (Optional) Other things that you do to MANAGE INTERRUPTIONS:

____

____

____

Q21 Do you believe, any of the following interventions could help mitigate / eliminate the effects of the most prevalent interruptions you experience in your daily work? (multiple answers possible)

- Red light / Do not disturb light at door
- Wearing a vest or some other signaling clothes
- (retractable) Barrier tape
- Headset radio to answer questions hands-free / give permission to enter
- Use of checklists to prepare each treatment

SECTION 4: DEMOGRAPHIC INFORMATION

The following questions will help us in managing the administration of the survey to ensure we have a good cross section of participants. Any personally identifiable data will be removed to protect your identity before information is shared.

Q22 Have you been observed during your work shift as part of the current interruption study?

- ❍ Yes
- ❍ No
- ❍ Not sure

Q23 What TIME OF DAY do you work most often:

- ❍ 8-12
- ❍ 12-16
- ❍ 16-20

Q24 How long have you worked as a dentist / hygienist?

- ❍ 0-5 years
- ❍ 5-10 years
- ❍ 10-15 years
- ❍ 15-20 years
- ❍ More than 20 years

Q59 What is your age group (years)?

- ❍ Less than 20
- ❍ 20 to 30
- ❍ 30 to 40
- ❍ 40 to 50
- ❍ 50 to 60
- ❍ Over 60

Appendix C: Provider Survey (POST)

SURVEY 2: Interruptions in a Dental Clinic – Post Intervention

PURPOSE OF SURVEY This survey was created by Carsten Ziegler (PhD in Industrial Engineering candidate at University of Louisville) to capture how an intervention to manage and prevent interruptions is viewed by dentists and hygienists working in a German dental clinic. Your participation in this survey will allow us to better understand the results of our intervention.

DEFINITION OF INTERRUPTION For this survey, please think of interruptions as anything that takes your attention away from a task or communication activity that you were already engaged in as part of your job.

DEFINITION OF INTERVENTION For this survey, please think of intervention as the process changes made – specifically the remote controlled “Do not Enter” sign.

CONFIDENTIALITY Your response to this survey will be de-identified before being shared. Identifying questions in the final section will be used by investigators during survey administration to make sure we have a good cross section of the dentist / hygienist population.

TIME TO TAKE SURVEY It is estimated that this survey will take 5 minutes to complete. We understand that your time is valuable and appreciate the time and effort you are giving in support of our research. (Check marks√’s, X’s, or filling in the spot with ANY color pencil or pen are ALL OK.)

SECTION 1: Please indicate your level of agreement with the following statements...

Q1 Interruptions **still** experienced while working on your patients ...add to your daily workload.
- ❑ **Strongly Disagree**
- ❑ **Disagree**
- ❑ **Neither Agree nor Disagree**
- ❑ **Agree**
- ❑ **Strongly Agree**

Q2 Interruptions **sti**ll experienced while working on your patients … lead to noticeable time loss / increased wait times.
- ❑ **Strongly Disagree**
- ❑ **Disagree**
- ❑ **Neither Agree nor Disagree**
- ❑ **Agree**
- ❑ **Strongly Agree**

Q3 Interruptions **still** experienced while working on your patients … have negative impact on your work satisfaction.
- ❑ **Strongly Disagree**
- ❑ **Disagree**
- ❑ **Neither Agree nor Disagree**
- ❑ **Agree**
- ❑ **Strongly Agree**

Q4 Interruptions **still** experienced while working on your patients … could place your patients at risk.
- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q5 Interruptions **still** experienced while working on your patients ...are sometimes beneficial.
- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q6 (Optional) Examples of interruptions you've noticed that may be BENEFICIAL TO PATIENTS OR YOU:

____

____

____

Q7 Interruptions **still** experienced while working on your patients ...cause you additional (negative) stress.
- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q8 Interruptions **still** experienced while working on your patients ...should be eliminated during critical procedures (e.g. bonding / adhesive steps, root canal filling, work close to apex)
- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q9 Interruptions **still** experienced while working on your patients ...should ALL be eliminated.
- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

SECTION 2: Please answer the following questions about interruptions you have noticed and WHEN (during which type of treatment) they occur...

Q10 WHEN do interruptions **now** occur most often that … could place your patients at risk? (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q11 WHEN do interruptions **now** occur most often that ...add to your daily workload? (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q12 WHEN do interruptions **now** occur most often that … lead to noticeable time loss / increased wait times (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q13 WHEN do interruptions **now** occur most often that … have negative impact on your work satisfaction? (Choose up to 3 responses)

- ❑ **Endodontics**
- ❑ **X-Ray**
- ❑ **Exam / Check-Up**
- ❑ **Treatment - Filling**
- ❑ **Treatment - CEREC**
- ❑ **Treatment - Perio**
- ❑ **Other** ____________________

Q14 WHEN do interruptions **now** occur most often that ...cause you added stress? (Choose up to 3 responses)
Endodontics
X-Ray
Exam / Check-Up
Treatment - Filling
Treatment - CEREC
Treatment - Perio
Other ___________________

Q15 (Optional) Please share anything additional you've noticed about WHEN interruptions occur **after the intervention**:

____

____

____

SECTION 3: Please answer the following questions about how often you use the technique stated to MANAGE INTERRUPTIONS you experience...

Q16 Do you use the following to MANAGE INTERRUPTIONS you **still** experience **with the intervention**?
"Wait to turn away from patient / toward an interrupting person until finished with current task."
- ❍ **Never**
- ❍ **Rarely**
- ❍ **Sometimes**
- ❍ **Most of the Time**
- ❍ **Always**

Q17 Do you use the following to MANAGE INTERRUPTIONS you **still** experience **with the intervention**?
"Take notice of interrupting person, but ask them to wait for a few moments."
- ❍ **Never**
- ❍ **Rarely**
- ❍ **Sometimes**
- ❍ **Most of the Time**
- ❍ **Always**

Q18 Do you use the following to MANAGE INTERRUPTIONS you **still** experience **with the intervention**?
"Write note to self as reminder to finish interrupted task."
- ❍ **Never**
- ❍ **Rarely**
- ❍ **Sometimes**
- ❍ **Most of the Time**
- ❍ **Always**

Q19 Do you use the following to MANAGE INTERRUPTIONS you **still** experience **with the intervention**?
"Ask someone else to remind you to return to interrupted task."

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Most of the Time
- ❍ Always

Q20 (Optional) Other things that you do to MANAGE INTERRUPTIONS:

____

____

____

SECTION 4: Please answer the following questions about your experience using the intervention to MANAGE INTERRUPTIONS you experience...

Q21 Did you experience any problems operating the remote control / do not enter sign?

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Most of the Time
- ❍ Always

Q22 Did you use the intervention during the procedures defined as critical per your job tasks?

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Most of the Time
- ❍ Always

Q23 The added steps (turning the sign on and off by remote control, disinfecting the remote control) add a noticeable workload to your tasks…

- ❍ Strongly Disagree
- ❍ Disagree
- ❍ Neither Agree nor Disagree
- ❍ Agree
- ❍ Strongly Agree

Q24 The intervention itself caused new interruptions that would otherwise not have occurred…

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q25 (Optional) Did you observe anything unexpected or any negative impact while using the intervention?:

____

____

____

Q26 Do you believe, this intervention helped mitigate / eliminate the effects of the most prevalent interruptions you experience in your daily work? (multiple answers possible)

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q27 The Intervention put in place ... eliminated interruptions during critical procedures (e.g. bonding / adhesive steps, root canal filling, work close to apex)

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

Q28 The Intervention put in place ...... eliminated ALL interruptions.

- ❑ Strongly Disagree
- ❑ Disagree
- ❑ Neither Agree nor Disagree
- ❑ Agree
- ❑ Strongly Agree

SECTION 5: Please answer the following questions to COMPARE your work experience before and after the intervention...

Q29 The work environment improved patient safety ......
- ❍ Strongly Disagree
- ❍ Disagree
- ❍ Neither Agree nor Disagree
- ❍ Agree
- ❍ Strongly Agree

Q30 The quality of my work improved….
- ❍ Strongly Disagree
- ❍ Disagree
- ❍ Neither Agree nor Disagree
- ❍ Agree
- ❍ Strongly Agree

Q31 The perceived time lost decreased?….
- ❍ Strongly Disagree
- ❍ Disagree
- ❍ Neither Agree nor Disagree
- ❍ Agree
- ❍ Strongly Agree

Q32 I felt less stressed….
- ❍ Strongly Disagree
- ❍ Disagree
- ❍ Neither Agree nor Disagree
- ❍ Agree
- ❍ Strongly Agree

Q33 My overall work satisfaction improved….
- ❍ Strongly Disagree
- ❍ Disagree
- ❍ Neither Agree nor Disagree
- ❍ Agree

Strongly Agree

CURRICULUM VITAE

NAME:	Carsten Ziegler
EDUCATION:	Dipl.-Ing., Wirtschaftsingenieurwesen Technische Universitat, Berlin, Germany, 2005
PROFESSIONAL POSITIONS:	General Manager Dental clinic in Germany 2016
	Strategic Key Account Manager GKN Land Systems 2014
	Sales Director International Gather Industrie 2012
	OEM Sales Director EMEA CamoplastSolideal Inc 2010
	Regional Sales Manager Europe Tuthill Coupling Group 2008