Tangible Business Process Modeling

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Tangible Business Process Modeling
Design and Evaluation of a Process Model Elicitation Technique

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Abstract

Business process modeling is the act of making explicit organizational knowledge about working procedures. Process models are diagrams that communicate activities, their routing order, documents, and responsibilities in visual graphs.

Process models are created by modeling experts, such as business analysts and consultants. Experts of the domain, e.g. clerks and managers, share their knowledge in interviews and workshops but the process model ultimately embodies the understanding of the modeling expert, the creator of the model. Possible miscommunication between domain and modeling expert results in serious consequences because process models often define future strategies and are used as blueprints in software-engineering projects.

This thesis introduces a new modeling technique which puts process modeling into the hands of the domain experts. The technique consists of a tool and method guidance for the tool application in group modeling workshops. The tool is a set of inscribable plastic shapes that is used to create process models on a table. The method guidance is a collection of best practices for modeling experts conducting workshops with domain experts.

This research investigates the new technique in exploratory studies, a laboratory experiment, and field research. The first studies explore the act of process modeling with the new tool. The laboratory experiment assesses hypotheses about the effect of the tool within individuals. For the field research, we team up with practitioners to develop the method guidance and compare the technique to existing workshop techniques in real conditions.

Moreover, this thesis contributes principles for modeling with domain experts based on literature research. The laboratory experiment compares the new technique with structured interviews. It shows that people modeling with the new technique are more engaged with the elicitation task and have more fun. Furthermore, they build more understanding for the process. And finally, they review and correct the model more often leading to more validated modeling results. The field studies with consultants contribute best practices for modeling workshops with the new tool. We also contribute a discussion to characterize situations that benefit from the new modeling technique. The field studies showed, that the new workshop technique is competitive in productivity and result to established software-supported modeling workshops.

This thesis focuses on the design and evaluation of a modeling technique that addresses the limited involvement of domain experts in current process modeling practice for the case of software requirements engineering. The idea was adapted to more fields of application. We conclude with an overview of these fields and a discussion on the broader applicability of the research findings.
Zusammenfassung

Geschäftsprozessmodellierung ist eine Möglichkeit das Wissen in einer Organisation sichtbar zu machen. Prozessmodelle sind Diagramme, die Aktivitäten, deren Reihenfolgebeziehungen, Dokumente und Zuständigkeiten veranschaulichen.


Beiträge der Dissertation sind u.a. eine Reihe von Grundsätzen für die Modellierung mit Fachanwendern, die basierend auf bestehender Literatur entwickelt wurden. Das Laborexperiment ergab, dass Anwender mit bei der neuen Modellierungstechnik engagierter sind, indem Sie der Aufgabe mehr Zeit widmen. Sie prüfen und ändern das Modell außerdem öfter, was zu stärker geprüften Modellen führt. Zudem berichten die Anwender mehr Spaß an dieser Art der Prozessaufnahme zu haben und ein tieferes Verständnis für den Prozess zu entwickeln. Verglichen wurde im Experiment die neue Modellierungstechnik mit strukturieren Interviews. Darüber hinaus diskutiert diese Dissertation Bedingungen, unter denen der Einsatz der neuen Modellierungstechnik lohnt. In der Feldforschung hat sich unter realen Bedingungen gezeigt, dass die neue Modellierungstechnik nicht hinter etablierten Methoden zurück steht bezüglich der Produktivität und erzieltem Ergebnis.

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1. Introduction

1.1. The world from a process perspective

Processes are sets of interrelated tasks and their dependencies. They exist everywhere in our environment. Whenever you play a game, buy groceries, or tie your shoes, you carry out a process. When observing carefully, you can identify smaller steps that are performed in coordination to reach the overall goal. Processes are not necessarily being made explicit but they exist implicitly as things are done. Being process-aware is a way to view the world. When you take this view then processes are ubiquitous.

Process models. When making implicit processes visible, one can describe them as a model. By model, we refer to the term of a scientific model: an abstract representation of the real world [128]. That means the model omits many aspects in favor for a simplified understanding of the core aspects. A process model at its core describes the steps taken and their order of execution. This can be enriched with further details such as the information processed or the output produced by that process. Process models are used to describe chemical reactions [127], scientific data analysis [78] or the work procedures in organizations [74].

Business process models. The work that organizations perform is captured in business process models. Business processes create value for the organization. The business process models capture how this value is created. They consist of activities executed in coordination within an organization to realize a business goal [147]. Order relationship between model activities is captured as control flow [118]. Business process models may also depict the information [116] or the resources [117] required in order to perform the process.

When organizations grew in size, it became more relevant to make business processes explicit in business process models in order to manage them [126]. While organizations are functionally structured, the business processes span across multiple functional divisions. As an example, an organization might be divided into order management, manufacturing, shipping, and accounting. When a customer orders a product, an order is placed, a build order is created, the product gets shipped and invoiced. The customer does not see the internal structure of the process but judges on the outcome, the time and quality of the delivered product. Business process models are used to analyze, communicate, and improve the internal flow of work within organizations.
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First attempts to introduce a common visual notation for business process models can be traced back to Frank B. Gilbreth in 1922 [46]. Gilbreth proposed ‘process charts’, today also known as flow charts. This notation was used and further refined in organizations throughout the 20th century [9]. When the term ‘process’ is used in this thesis, we always refer to business processes. In some communities, this is synonym to the term ‘workflow’ [76, 74]. It refers to the set of tasks in an organization performed in coordination to reach a goal. For us the term ‘workflow’ and ‘business process’ is the same but we mainly use ‘process’ for short.

Stakeholders in business process modeling. People that perform tasks in business processes are described as ‘resources’ [117] in a process model. They are not necessarily aware of the processes they participate in because they get assigned a small part of it, such as the shipping of products in a large manufacturing company. We refer to them as the domain experts. They are the people that work in the process every day. They know the details crucial to successful realization of process steps.

Visualizing process knowledge is the job of business process modeling experts, short BPM experts. They know how to elicit process knowledge and have typically received special training in using a particular modeling notation. Some are even certified by organizations that define standards for process modeling¹. In any case, they are experienced in conceptualizing other people’s knowledge into business process models.

Many more people have a stake in business process modeling, e.g. the managers that gain an overview about the current state of the business operations and decide about alternative future ways of working. Furthermore, public accountants audit whether processes are performed as defined in the organizational handbook and as required by legislation. Finally, software engineers have become an important stakeholder in business process modeling. When work shall be automated in software systems the business process models describe how systems and people interlink.

Business process models are mission critical: one specific case. LISA corp. was a federal funding agency at which legitimate environmental projects applied to receive funding. LISA assessed projects, paid funding, and claimed refund from European authorities.

In 2006, LISA decided to purchase new software to support their core processes. They hired an external consultant – a BPM expert – to prepare a call for tenders. The consultant performed interviews with clerks from LISA, the domain experts. As a result, he created a set of business process models describing how LISA corp. will work in the future given new software. The process models were used as part of the requirements definition in the call for tender.

Software solution providers applied based on these requirements. The software company with the best offer was asked to implement one representative business

¹http://www.omg.org/oceb/
process as a proof of concept. Finally, the software was bought and installed. A software consultant configured the new software system according to the process models and the software went productive in 2008.

In this case, the process models were part of the requirements engineering, they were part of the sales process in the call for tenders, they also became part of the software documentation after configuration according to the process models. Finally, the process models were used in the organizational handbook to document the work of LISA. People that based their work on these models became stakeholders. Those are the clerks and the head of LISA corp., the sales persons at the software companies, and the software consultants implementing the proof of concept and the final system. They all relied on the process models.

Unfortunately, there was a small glitch in the models: payments could go to non-legitimate projects because not all prerequisites were adequately checked neither by the clerks nor by the software system. Nobody recognized the problem until another stakeholder found out, the auditor from the European funding agency. LISA corp. did not receive further refund for already funded projects. In 2010, LISA corp. went out of business.

Besides mistakes that might have happened on the way, it all started with miscommunication between two stakeholder groups, the domain experts and the BPM expert. Capturing knowledge in process models is a critical task but it is only half accomplished if the process models are not understood and validated by the domain experts, the knowledge carriers. Further steps, rely on accurate process models as input. Flaws in process models get amplified when the process is implemented using information technology.

1.2. Processes in information technology

When the first mainframe computers were introduced to organizations, the business processes were largely affected by the new opportunities provided with information technology (IT). The potential of information technology could only be leveraged if the business process and IT design go together [59]. Therefore the IT experts had to understand the business operations and match them with the potential of latest technology. In 1993 Hammer and Champy proposed to reengineer the corporation by setting up mixed teams of domain and IT experts [59]. Each team would redefine and implement one business process by leveraging the potentials of information technology. At that time, all larger companies performed reengineering projects in which traditional work was (partially) automated with software and business processes were redefined as a result. At latest at that point, business processes were no longer an organizational topic alone but became a topic in software engineering as well [141].

**Build to change.** Today, software systems are a crucial infrastructure in organizations. Some software systems perform one specific functional task, e.g. accounting or item tracking. Others interface with various functional systems to coordinate the work performed in the software system landscape, called process-aware information
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systems [33]. These systems are configured with formal process definitions. These are business process models that contain the information required to be executed by a computer, analogue to a programming language.

This has been made possible due to formal advancements in business process modeling [147], model verification algorithms [143] and standardized serialization formats [99]. Software that is configurable with process models enables more flexibility. Earlier, the process and the IT system were implemented together. Now, one can keep the software system and change the process based on its description. That lowers costs and accelerates the time to adoption [126]. It is also a corner stone for the transformation of business knowledge to software. The model that describes the business operations gets refined until it is executable by a computer.

There are more ways of using business process models in IT. Indeed, most process models in that domain serve as requirements documents in software implementation projects. They are created to better understand the business context in which the software is going to be used. This allows locating the functionality in a process model and to better support the flow of work with the software system.

Process modeling languages. A large variety of business process modeling languages has been created in the last two decades, e.g. UML Activity Diagrams [32], WS-BPEL [99], EPCs [67], BPMN [99] or YAWL [142].

Modern process modeling languages capture control flow, data flow and resource allocation [118, 116, 117]. In other words, they depict ordering relations between activities, information that is processed, and people or systems to perform the activities in the process. More technical modeling languages additionally capture exception handling and compensation [99, 56]. These aspects are relevant for software executed processes and they are not necessarily communicated with domain experts. Until recently, there was even a distinction between organizational and technical process models. For example BPEL [99], the most successful standard for process automation yet, does not even have a graphical notation. It was designed for business process automation not for communication with domain experts. This paradigm is changing. Organizational models can be transformed or refined to technical models. An integrated tool-chain is envisioned from organizational to technical processes. At present, two process modeling languages stand out because they are the most commonly used in practice [153, 119], EPC [67] and BPMN [64].

The Event-driven Process Chain (EPC) was introduced in the 1990s by IDS Scheer. It was bundled with a holistic organizational modeling concept and backed up by sophisticated software tooling to create, analyze and distribute models. Thus, it found wide adoption in organizational modeling and became the dominant standard of the turning century. EPCs are not meant for process automation, but the models capture IT systems utilized in the process making it a suitable input for software requirements engineering. Moreover, the tooling later enabled the creation of BPEL [99] skeleton source code from EPC models that could be further refined to executable BPEL processes.

In 2004, an industry consortium around software vendors started standardizing [64, 54, 55] the Business Process Modeling Notation (BPMN). The aspiration
was a modeling language suited for business users and the configuration of software systems alike. While the graphical notation is inspired by the well-adopted flowcharting notations \[9\], the execution semantics is based on BPEL \[99\]. This combination created a language suited for communication among stakeholders and the configuration of IT systems. The latest version from 2011 adds formal execution semantics and a standardized exchange format \[56\]. A large consortium of industry vendors, e.g. IBM, Oracle and SAP, pushes BPMN. More than 70 software tools are listed as supporters\(^2\) of this new standard by now. It is a leap forward towards interchangeable process-based software configuration. Unlike the other technically spawned languages, it is also well adopted by the business units because it is based on the already popular flowcharting notation \[9\]. Finally, there is a chance for one modeling language shared by all stakeholders.

**Shared understanding.** Business process models are used to ease communication among stakeholders. They can build a shared understanding of the work procedures, such as the path from ordering to shipment of goods. This becomes more important as models are used as requirements documents for software engineering projects or even as configuration for IT systems. BPMN \[56\] enables one streamlined modeling language for business units, IT units, and software configuration.

As process modeling languages become more sophisticated, more expert knowledge is required to master them. Domain experts – occasionally involved – struggle to understand the various notational elements and concepts that are embodied in modern process models. If models are not properly understood and validated by the domain experts, misunderstanding leads to wrong implementations downstream in the software engineering project \[106\]. We illustrated this in section 1.1 by example. LISA corp. went out of business because domain experts were not properly involved in shaping and validating a process model that was later on used to automate core processes of the organization.

LISA corp. is one example why process modeling – the act of creating models based on a shared understanding – is a crucial task. This thesis investigates the act of process modeling as the task of creating and validating shared understanding with domain experts.

### 1.3. Existing process elicitation techniques

Business process modeling experts (BPM experts) acquire the process knowledge about an organization in interviews and workshops from the domain experts. This activity is referred to as process elicitation. Choosing the method of elicitation is up to the preferences of the BPM expert, his/her knowledge about the domain to be modeled, and the resources available for the project. We describe typical situations for process elicitation in the following subsections.

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1.3.1. (Un)structured interviews

An interview is a one-to-one situation. It can be structured with questions to be answered or held as an open (unstructured) conversation. The BPM expert meets a domain expert to elicit information about the process. If many people are involved in the process, multiple interviews need to be conducted. After a set of interviews, the BPM expert consolidates his/her understanding of the situation into a process model that describes how a particular part of the work is performed in this specific organization. A process model is created after the interviews based on the notes and understanding of the BPM expert. In some cases, the resulting model is discussed with the domain experts for validation.

Pro: This elicitation technique is highly efficient if the BPM expert already knows the domain, the terminology, and the standard process to be elicited. The interviews can be reduced to a minimal set of questions that work out the differences to the anticipated standard process. For example, a BPM expert specialized in logistics may know all variations of the goods-receipt-process. He questions the domain experts to verify his/her understanding and proposes a tailored standard process.

Contra: Interviews assume that the BPM expert and the domain experts share the same terminology and background. If this is not the case, interviews bear a high risk for misunderstandings, which may even result in companies crashing, such as in the case of LISA corp. in section 1.1. If domain experts make varying statements during interviews, further interviews are required to resolve conflicting views among the domain experts. That delays the elicitation process and creates extra work for the BPM expert.

1.3.2. Software-supported workshops

A workshop is a group situation with at least one BPM expert and multiple domain experts in the same room. The BPM expert moderates a discussion about the process to be elicited. The participants ideally interact with each other to create a shared opinion. Notes might be produced to collect process-relevant information. The process model can be created based on these results. Most commonly, the process model is created during the workshop with a software-based modeling tool. Therefore an additional BPM expert participates, the software tool operator. He translates the discussions into a process model on the fly. The model is simultaneously projected to a wall so that it can be reviewed by the workshop participants.

Pro: Workshops are best suited for situations in which the process model creation requires discussion among the domain experts, e.g. for future process designs. Participants can negotiate the process during the workshop. Using modeling software, a digital process model is created as the immediate workshop result. The intermediate model can serve as a reference point during the discussion. It can be
reviewed together and changed based on comments from the workshop participants. Finally, the digital process model can be shared easily with all participants after the workshop.

Contra: This workshop technique requires a team of two BPM experts well-practiced in those workshop situations. One BPM expert moderates the group; the other one is the tool operator that creates the process model. The tool operator also takes design decisions. Thus, the model actually reflects his/her understanding of the discussion. The participants can demand changes if they understand what the model means but they have to explain the changes to the tool operator again. In other words, the participants have to channel their input through the tool operator which slows down the creative process [131]. Direct interaction with the process model is not possible.

Finally, creating a model together is supposed to foster a shared view but limited screen resolution of standard projectors makes it hard to keep an overview of the model for the workshop participants.

1.3.3. More workshops styles

A range of methods exists to facilitate process elicitation in workshops. We mention two more extreme cases to complement the picture. Yet, they are not as common as the ones mentioned above.

Brown-paper workshops. Using paper taped to a wall, markers, and Post-Its, a group can work together on the information relevant for the process. This is a traditional workshop experience with all participants working together on one result. This is sometimes referred to as Metaplan3 process modeling because the company provides workshop material including activity shapes for pinboards. The result is typically not a BPMN or EPC conform process model, therefore translation of the gathered information into a proper process modeling language is required.

Collaborative software process modeling in workshops. In this case, the workshop participants directly work with a software tool to map out information. In a round-based game, first activities, later routing orders, are defined. Results from one round are rated by the other participants. The highest rated result is the starting point for the next round. The tool and method is inspired by game theory and assumes that people enjoy the competition and the work with the computer in the workshop. This technique is ongoing research[113]. We discuss it in more detail in the related work section 2.2.

1.3.4. Problem analysis for existing process elicitation

In the most common scenarios used for process modeling – interviews and software-supported workshops – the process model is created by BPM experts. The domain

3http://www.metaplan.us/
experts have only limited influence on the process model creation. They are questioned but not engaged when their statements are translated into the actual process modeling notation. There is a barrier for the participants to engage with the process model directly, e.g. because the model is created offside when the domain expert is not present. If the model is created during workshops it is guarded by additional expert knowledge, the software tooling. BPM experts use sophisticated software tools, such as ARIS\textsuperscript{4}, which require additional training and expertise. The participants have to channel their input through the tool operator into the model.

Given the relevance of the process models, e.g. as input for software engineering projects, it is crucial that domain experts can express their knowledge properly in process models. They have to read, understand and question it. Misunderstandings lead to approval of immature models or refusal of correct models. Immature models cause effort in later stages when they meet reality. Refused models lead to additional effort to explain the model and establish a shared view.

Less common approaches, like brown-paper workshops or software modeling games, engage the domain experts to shape the information in the model. However, brown-paper workshops do not produce a proper process model. Again, the model is created separate from the elicitation in the workshop. The collaborative software process modeling game solves this problem, but it has another strong assumption: domain experts enjoy working with computers in workshops. This assumption might not hold for all audiences, e.g. those that do not work with computers in their daily job. However, this idea is not widely adopted but ongoing research, which will be discussed in more detail in section 2.2.

1.4. Research objective and goals

We seek to facilitate the process-oriented communication between the key stakeholder groups, the domain experts and the BPM expert. The modeling techniques practiced today assume that process models are best created by BPM experts. The domain experts are questioned or asked to map related information but they are not creating the process model itself. We think it is possible to engage domain experts with their process models directly. Thus, we set the following research objective:

\textit{Design and evaluate an approach to engage domain experts in the creation and validation of their process models.}

We know that the knowledge for processes is typically spread amongst many domain experts in the organization. The new modeling approach should therefore bring people together. The approach should also yield advantages over existing approaches, such as more engaged domain experts or better process models. Finally,

\textsuperscript{4}http://www.softwareag.com/corporate/products/aris_platform/
we want the solution to be realistically applicable in daily BPM practice. We take these aspects and form the following goals for this research:

1. Create a group modeling experience.
2. Compare the solution to existing approaches.
3. Ensure the solution is applicable in practice.

The research is led by the research objective. The goals are orientation points to further sharpen the research agenda. We derive research questions towards these goals for each of the research phases as we go through them.

**1.5. Research framework and research methods**

This research was funded by the HPI-Stanford Design Thinking Research Program\(^5\). Design Thinking is an innovation method that emphasizes ideation, prototyping, user testing and iterations. The research program supports, among others, research that combines Design Thinking with traditional approaches in the field of engineering [105]. For the first phase of ideation and design, we got inspired by Design Thinking principles. Afterwards, we use established scientific methods to evaluate the solution.

This work can be seen as ‘design science research’ referring to a framework [60, 148] to guide researchers designing and evaluating artifacts. The term ‘design science’ was coined by Hevner in 2004 for information systems science but the principles can be applied to all engineering disciplines. At its core it suggests to select a relevant problem from practice, create an artifact as a solution, and assess the solution with scientific rigor. Artifacts might be software, hardware tools or methods. Assessment leads to new insights and the artifact is iterated. In other words, design science proposes to alternate between design and evaluation of a solution. The design science framework proposed by Hevner is depicted in attachment A.1. Attachment A.2 illustrates our research in Hevner’s framework. In 2010, Wieringa proposed a design science framework that is in-line with Hevner’s ideas but puts emphasis on the distinction between the practical problem solving and the research question investigations. This framework is depicted in attachment A.3. This research in the light of Wieringa’s framework is shown in attachment A.4.

In the following, we describe the empirical research methods used in this thesis to design, evaluate and iterate the research artifacts. We intend to provide an overview and a precise terminology.

**Prototyping.** Prototyping is the embodiment and testing of ideas [31]. A prototype does not necessarily reflect all qualities of the envisioned solution [68]. It elaborates on aspects of the solution with e.g. rough material or improper sizing. Prototyping should be a cheap and fast way to validate or falsify ideas. Prototyping is not a scientific research method but it enables effective goal-oriented progress. We use prototyping to gain fast feedback and iterate early ideas.

\(^5\)http://www.hpi.uni-potsdam.de/forschung/design_thinking_research_program/
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**Exploratory studies.** Is a type of research that starts without a hypothesis definition [138] but with the intend to explore situations and determine a suitable research design. We use case studies and experimental setups in the exploratory studies. Experimental setups compare situation under changing conditions [150]. In case studies, we intensively observe one case in its real life context [17]. The exploratory studies contribute to our later investigations e.g. in the form of hypothesis building and preliminary data collection.

**Controlled experiment.** A controlled experiment is a manipulative research method. It compares groups in different treatment conditions to validate hypotheses about the co-occurrence of effects with treatment [150]. In other words, one group receives a special treatment (treatment group) the other group has the same conditions but without the special treatment (control group). The effect is described as an hypothesis for the treatment group. Statistical analysis is performed in which the treatment is the independent and the expected effect is the dependent variable. In other words, the treatment is supposed to explain the observed effects. We use this method to assess hypotheses about the effect of our solution on individual people.

**Action research.** Action research is a field research method. It acknowledges that not all problems can be reduced to meaningful artificial settings for study. It offers guidance to researchers that act in professional contexts.

Action research combines changes in a complex social system with the creation of knowledge about the effect of change [75, 132] through scientific investigations. It seeks to create practically applicable solutions and generate scientific knowledge at the same time. The knowledge builds up through multiple iterations of a learning cycle. We use action research to advance and evaluate our solution in professional settings together with practitioners.

### 1.6. Contributions

This thesis describes the design and evaluation of a process modeling technique that enables domain experts to conceptualize their knowledge into process models. The proposed modeling technique consists of a toolset and a method for application. The concepts are realized in the TBPM toolkit and the TBPM method cards as practical contributions to BPM experts using this technique and as a side product of this research.

The scientific contributions of this thesis are condensed in figure 1.1 and discussed in the following listing:

- A set of principles for working out conceptual models together with domain experts. This is based on a review of scientific literature from cognitive science and design research in chapter 2. As an example, we propose to map out information using an expressive representation and an intuitively usable tool. These principles become design considerations for our solution, a tangible modeling toolkit.
1.7. Publications

Many of the contributions in this thesis have already been published at workshops and conferences, in technical reports and books.

The initial idea of tangible process modeling were first published to the design research community at the International Conference on Engineering Design (ICED2009) [35]. Shortly afterwards a problem description, the initial idea and possible evaluation paths were published at the International Workshop on Empirical Research in Business Process Management (ER-BPM2009) [52].

We then published a stronger theoretical analysis of the problem and discussed the transferability of the tangible modeling idea to further fields at the 8th Design Thinking Research Symposium (DTRS8) [80]. We also formed a set of principles for the application of modeling tools with non-professional modelers that was published...
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at the International Participatory Innovation Conference (PINC2011) [79]. The problem analysis, the prototyping journey, and a first comprehensive research outline was first published as part of the book ‘Design Thinking – Understand, Improve, Apply’ [81].

A series of exploratory studies was published in the Electronic Colloquium on Design Thinking Research (ECDTR) [82]. The controlled laboratory experiment was published in full-length as the 41st technical report of the Hasso-Plattner-Institute [83]. Smaller aspects of the experiment were cut out and discussed at (1) the International Workshop on Empirical Research in Process-Oriented Information Systems (ER-POIS2010) [53], (2) as part of the book ‘Studying Co-Creation in Practice’ [84], and (3) at the International Conference on Advanced Information Systems Engineering (CAiSE2011) [86]. Finally, the action research studies were published at the International Workshop on Empirical Research in Business Process Management (ER-BPM2011) [85].

1.8. Outline of this thesis

Figure 1.2 illustrates our research framework and how this is followed by the outline of this thesis. In chapter 1 we have described commonly used techniques in business process modeling practice. From existing practice, we derived problems and the research objective. In chapter 2 we review related scientific literature on software requirements elicitation, cognitive science and design research. The findings from existing literature guide us in chapter 3 when designing and exploring a first solution through prototyping and exploratory research studies. The solution proposed is called Tangible Business Process Modeling (TBPM).

In chapter 4 we evaluate hypotheses about the effects to be expected with our solution (TBPM) in a controlled laboratory experiment. We identify significant
differences for people using tangible media, in particular TBPM, for process modeling in comparison to structured interviews. In chapter 5 we design, evaluate and iterate a method to facilitate TBPM workshops. We use action research as the scientific method to guide the collaboration with practitioners in this phase. The application of TBPM in real projects shows the relevance of the tool to practice. In chapter 6, various fields of application are shown in which tangible modeling has been applied. Most of them go beyond the process elicitation workshops scientifically evaluated in this thesis. We discuss the findings and their broader applicability in the concluding chapter 7.
2. Related research

This work has been influenced by knowledge from multiple research disciplines. At first, we review research on information elicitation and modeling from software engineering and information systems research. Afterwards, we inspect research from cognitive science and design research. We condense the related research knowledge into a set of basic principles that guide the solution design in chapter 3. The principles are listed in section 2.6.

2.1. Review studies on requirements elicitation techniques

There is a rich set of research about knowledge acquisition and requirements elicitation for software engineering. We therefore focus on two review studies that review and compare existing research. They summarize the state of knowledge about a topic and generate more abstract findings about this research domain. It is in our interest to obtain a big picture about the state of research on elicitation techniques.

Variety and best practice. In 1992, Byrd et al. [15] examined the most commonly used techniques in knowledge acquisition and requirements elicitation for information systems. Techniques are clustered as observations, (un)structured elicitation, mapping techniques, and formal analysis. As examples, card sorting [42] and scenario descriptions [10] are structured techniques, while open interviews [28] and brainstorming [136, 137] are unstructured techniques. Protocol analysis [151] and behavior analysis [21] are observational techniques, while machine rule induction [94] and text analysis [21] are formal analysis techniques. In all cases there is a requirements engineer that elicits the information from a domain expert to acquire the knowledge needed to build a software system. Process understanding is most commonly gained by observations, mappings or structured interviews. The techniques are qualified according to the drivers of the elicitation. In general, the more formal the model that is built, the more likely it is to be driven by the requirements engineer and not by the user. The authors suggest that it is best practice to listen to the user, e.g. in interviews, and to give limited influence to predefined design decisions, e.g. in workshops.

Effectiveness of requirements elicitation techniques. In 2006, Davis et al. [27] reviewed studies that compared the effectiveness of different requirements elicitation techniques used in software engineering. While the paper uses the term ‘effectiveness’,
the studies compare elicitation techniques mainly by the amount of information mapped. The reviewed studies found structured interviews to create more information than unstructured interviews [2, 95]. Unstructured interviews in turn gather more information than card sorting [12, 123] or thinking aloud techniques [14, 23]. The structured interviews are therefore named the most ‘effective’ elicitation technique.

Interestingly, analyst experience does not seem to have an influence [2, 104] at least for interview techniques. Furthermore, the presence of visual aids or prototypes has not been found to create more information [48, 96]. The authors note that the results are not very robust given the various contextual differences (problem type, subjects’ background) in the studies, the small sample sizes, and the lack of replicated studies in computer science. The authors therefore call for more research comparing requirements elicitation techniques.

2.2. Research on process group modeling techniques

Group modeling techniques are applied in moderated workshops. Many techniques are developed as best practices in companies but are never investigated scientifically. The following research investigates two workshop styles already mentioned in section 1.3.

**Participative enterprise modeling.** Persson [100, 101, 131] investigated a technique for enterprise modeling in which the model is created during a workshop with domain experts by a dedicated software tool expert. They modeled business rules, processes, and organizational charts using Microsoft Visio as a software tool. The model is projected to the wall for participants to review it. While the workshop participants concentrate on the content, the modeling expert concentrates on operating the software. This technique is the same as the one described in section 1.3.2 as software-supported workshops. Persson found that this type of participation leads to enhanced quality, stronger consensus, acceptance and commitment to the modeling results [100] compared to non-participative approaches, e.g. interviews.

However, the participants do not directly engage with modeling and are limited to providing feedback to a model that others create. In one case [131] Post-Its were used to document the model because the technical setup was broken. The researchers noticed Post-Its were useful because it did not require the modeling participants to ‘channel’ their input to the model through an operator of a computerized tool, which ‘often slows down the creative process’ [131]. After the modeling session the facilitator documented the resulting models in the software tool. Apart from this exception, participation is limited to reviewing a model while it is created. Yet, this technique was found to yields the described positive effects when compared to non-participative model building techniques, such as interviews.

**Collaborative business process modeling.** From interviews with practitioners Rittgen identified the most pressing problems when conducting group modeling work-
2.3. Empirical research on business process modeling

Process modeling is rooted in two research communities, information systems (IS) research [19] and business process management [147] as a discipline of software engineering. We discuss the literature from both communities separately by means of the popular empirical research methods in each area. Nevertheless the communities overlap with some researchers publishing in both communities, e.g. [107] and [108].

**Information systems research.** In 2009, Bandara [5] did a literature review on the research methods used in IS to investigate business process modeling. The review spanned 99 papers from high-ranked IS conferences and journals based on the keywords ‘process model*’ and ‘process map*’. This review does not include the studies mentioned in section 2.2 because Perssons work [100, 101, 131] does not match the schema of the literature extraction method and the studies by Rittgen [111, 113, 114] are more recent. From this review, we focus on twenty-six papers that used empirical research methods to quantify their popularity.

According to the review [5], case studies and experiments are the most popular empirical research methods in IS. Fourteen case studies have been identified such as the work by Chan and Rosemann [18] on the integration of additional information, despite activities and their control flow relation, into process models. Seven experiments have been collected such as the work by Mendes [89] on the effect of process modeling initiatives on organizational change. The term experiment is defined in this review [5] as actions to support or falsify a hypothesis. Surveys, such as the work by Green [49], were found in three papers. Green performed an ontological analysis of process modeling terminology based on the survey.
conducted. Protocol analysis [38], a method to elicit insights from verbal reports, was only found in one occasion [26]. One more paper was listed that uses a mix the aforementioned methods [69].

Interestingly, action research [75] as an empirical method was listed in the review but no publications related to process modeling were found. One example for that is the work by Rittgen discussed already. He develops a group modeling method in the field and calls it [115]: a combination of design science [60] and action research [75].

Business process management. Empirical work on process modeling in the business process management community has gained more attention as (1) a way to understand the business and to understand the (2) act of business process modeling.

To draw needs and insights from industry, case studies and delphi studies are performed. A delphi study is an iterated structured questioning with groups of experts [77]. After each iteration, the answers are shared with each participant leading to a group consensus after some iterations. It was originally developed as an interactive forecasting technique. For example, Indulska et al. [63] performed a delphi study to understand future challenges in business process modeling. They found standardization of modeling languages, value of process modeling, and stakeholder buy-in as the most pressing needs in business [63]. Reijers et al. [109] performed a case study to characterize the business roles involved in business process modeling from two industry scenarios.

The act of process modeling is researched on different levels. As one, model collections are evaluated to identify common usage patterns [153, 51] and the relation of process model attributes to formal modeling error [90]. The accumulation of this type of research leads to modeling guidelines [92] for trainers and practitioners of process modeling.

The most emerging type of empirical research in business process management is done in controlled experiments in which groups in different conditions are compared in well-designed settings. This was done to understand different work strategies in process planning [146] and execution [98]. For example, Weber et al. investigated the influence of constrains on the planning strategies of users [146]. Repeating experimental work creates higher standards for experimental investigations and evaluations [150]. One manifestation of higher standards is software specifically designed to conduct controlled experimental research, such as [146, 102]. As one example, Pinggera et al. [102] created an experimental platform to investigate the act of process modeling with a software tool. This is ongoing research with first attempts [103] to visualize and understand the information gathered with this type of experimental support.

In parallel to these efforts, Houy et al. [61] are investigating the theoretical foundations of empirical research in business process management by means of structured literature analysis, similar to the work of Bandara et al. [5]. The goal is to facilitate the building of a shared terminology as well as shared theory to build upon in the business process management community. Again, this is work in progress.
This thesis is routed in the business process management community with touch points to other communities, which we discuss in the remaining related work. The controlled laboratory experiment in chapter 4 contributes to the rising standards for empirical research. We also conduct a case study in section 3.5 as part of the exploratory investigations. With the action research studies in chapter 5 we go beyond the methods commonly used to investigate business process modeling [5, 61] as we discussed above.

2.4. Cognitive theories

Research in cognitive science investigates the nature of the human mind. It seeks to understand perceiving, thinking, learning, understanding, and other mental phenomena [130]. The goal of this research is to find and describe effects that are consistent in human information processes. The resulting body of knowledge is the groundwork upon which researchers in psychology, linguistics, computer science, philosophy, and neuroscience build. Our interest is to understand the cognitive effects that non-professional modelers are exposed to.

Cognitive load. Cognitive loading refers to the limitation of the human to process information in logical linear fashion. Miller was one of the first to describe the limitations of the human brain for its ability to process single-dimensional information [93]. He demonstrated that the average person can hold on to ‘seven, plus or minus two,’ single dimensional stimuli in its mind at a time. Miller also showed that the ability to remember and discriminate information can be dramatically expanded by adding dimensional stimuli. Dimensions for stimuli can be color, sound, material or space. Multidimensional stimuli enable humans to hold on to much more information.

Mental effort. The mental effort is a perceived index to measure the cognitive load. It was put forward by Sweller and Chandler proposing a cognitive load theory for learners [135]. The learning process is deconstructed into several factors: (1) intrinsic load, the complexity of the learning topic itself, (2) extrinsic load, the manner of representation, and (3) the germane load, influenced by the didactic of the learning process. While the capacity of the brain is fixed – called the working memory – the mental effort for a learning task can be manipulated. Sweller and Chandler found that intrinsic load cannot be influenced but the representation and the didactic of the learning process can be manipulated to influence the mental effort. In other words, improving the didactic of the learning process can reduce the cognitive load and free working memory for the primary task.

Cognitive fit. Since people are limited as information processors, they try to reduce their cognitive load by fitting the representation to the problem to be solved, called cognitive fit [144]. This theory postulates that there is more or less suitable representation of information according to the problem domain. It was used in empirical studies to explain performance differences in problem solving [145]. The
cognitive fit has also been investigated by computer scientists for process-oriented vs. object-oriented problems [1]. Superior problem solving performance was found for situations in which problem and representation match.

2.5. Design research

The term design research is excessively used in various areas with different meanings, such as information systems [140], mechanical engineering [34] or Design Thinking [47]. It is as ubiquitous and ambiguous as the word ‘design’ itself. Our interest is in research from mechanical engineering design about the role of information embodiment and media-models.

**Information embodiment** The embodiment of information in a specific representation creates an intermediary object. This object is shared amongst people and thereby enables distributed cognition [11]. As one example, process models are intermediary objects to be shared amongst people. Thinking is distributed when the stakeholders individually review the information represented in the process model.

The media chosen for the embodiment of the information, e.g. in plasticine or steel, determines affordances. Following Gibbons [44], affordances are perceptual cues of an environment or object that indicate possibilities for action [45]. For example, a car created of plasticine indicates different possibilities for interaction compared to a car made of steel. Intermediary objects provide affordances for thinking and action, because they condition how information is perceived and what can be done with it.

**Media-models theory.** The media-models theory [35, 36] builds on the idea of intermediary objects and affordances. It proposes that media-models have affordances that steer the conversation in design. Models are intermediate representations, as described before, and they are a proxy for the actual thing to be discussed. The media brings about affordances that become qualities of the model as well.

The media-models are characterized by the dimensions of resolution and abstraction [35]. Resolution refers to the fidelity with which an object is defined with respect to its final form. Abstraction is defined as the highlighting and isolation of specific qualities and properties of an object, such as color, size or functions. Fewer represented properties indicate a greater abstraction.

Highly resolved and less abstract media-models have been observed to foster small parametric adjustment to the shared representation. The model – the proxy for the actual thing – is mistaken for the actual thing and changes are made with care. In contrast, lower resolution and highly abstract media-models, like rough physical prototypes, afford more and radical changes. The roughness of the media-model makes it useless to discuss small parametric adjustments [36].

For example, a car concept may be discussed using a model realized in stone, foam or a cat drawing. Discussions about the car and changes to the concept are different depending on the type of media chosen for the model.
2.6. Principles for model building with domain experts

We reviewed research in cognitive science to better understand human information processing. This is enriched with findings from design research about the role of information embodiment and the role of media for models that are used in the design discussion. In this section, we derive principles for modeling experts working with domain experts, non-professional modelers. These principles broaden our understanding about model building. They are the starting point to prototype new elicitation techniques in chapter 3. The principles are as follows:

- **Map out the information**: People have limited information processing capacity [93]. Mapping information can help to reduce the cognitive load and extend capacity to hold on to details by adding new stimuli to the information.

- **Choose an expressive representation**: Representation impacts the problem solving performance [144, 145]. Optimal performance is achieved when problem and representation fit which means they emphasize the same aspects. This was also shown for process-oriented vs. object-oriented problems [1].

- **Make it intuitive to use**: Humans have limited working memory which is consumed by different types of cognitive load [135]. Reducing external load, e.g. by providing intuitive tooling, frees capacity for other concerns [134]. This is particularly important for non-professional modelers.

- **Fit media with model purpose**: The embodiment of shared information conditions the communication about and interactions with the information [11]. In other words, these objects have an active role in communication. This is in particular relevant for model building as the media chosen influences resolution and abstraction of the model [35] which steers the design discussion.

2.7. Summary of findings from related research

We have reviewed literature on requirements elicitation and process modeling. Afterwards, we derived four principles for model building with domain experts based on scientific theory from cognitive science and design research.

**Requirements engineering and process modeling.** A plurality of information elicitation techniques has been scientifically investigated already. In essence, best practice is to interview the domain experts, have the model built by a modeling expert, and provide limited influence on predefined design decisions in workshops [15]. When comparing information elicitation techniques [27], structured interviews perform best in comparison to e.g. open interviews or card sorting techniques.

This practice detaches the domain user from the model. But model building together with the domain experts is recognized as crucial [101, 100, 131, 114, 115]. The software-supported workshops – as characterized in section 1.3.3 – have been
2. Related research

researched by Persson. She found enhanced quality, stronger consensus, acceptance and commitment to the modeling results using modeling software, a projector and a dedicated tool operator in workshops. She compared to interviews as the non-participative approach.

Rittgen [114, 115, 112] developed software tooling to be used by domain experts during workshops. He addressed, among other aspects, low model acceptance and the misunderstood participants as crucial needs. He achieved stronger participant involvement and perceived higher model quality [112] compared to brown-paper modeling, also characterized in section 1.3.3. His underlying assumption is that people like to work with software in workshops.

In information systems science, there is an emphasis on understanding the needs in industry to provide answers, e.g. [63]. The business process management community is particularly interested in the analysis of models [153, 90, 51] and – more recently – into the analysis of model creation using experiments, e.g. [102, 103]. This work is located in the business process management community and contributes to the body of knowledge by providing experiment results about the differences of modeling techniques.

Four principles derived. We broaden our scope with research from cognitive science [130] and design research [34]. From there we derive four fundamental principles for model creation with domain experts. We propose to (1) map information which reduces the cognitive load of learners [133], to (2) choose a representation which fits the cognitive problem domain [1], to (3) create intuitive tooling which frees working memory of participants [97], and to (4) choose media that has affordances in-line with the intention of the tool [35]. We use these principles in chapter 3 to guide us in the prototyping process towards the solution design.
3. Building the TBPM toolkit

Our objective is to design a process elicitation technique that engages domain experts with process models. We set the goal to make this a group modeling experience. In this chapter, we seek to answer the research question ‘How can a solution look like that makes process modeling a group experience?’.

This question spawned a series of prototypes, which led to the creation of the TBPM toolkit. This chapter describes the journey towards a solution and first exploratory research with the toolkit. The first steps of our research were published in more detail in [37, 52, 81, 82].

3.1. Initial prototyping

This research was funded by the HPI-Stanford Design Thinking Research Program (see also section 1.5) and therefore inspired by Design Thinking. At its core, Design Thinking fosters prototyping and fast feedback from the target audience. We adopted the prototyping paradigm for the first steps towards the research.

The initial prototyping was driven by the vision of role-playing. Instead of discussing the process, participants would undergo it. We chose a shop scenario involving customers, the shop front-end and back-end, as well as banks and suppliers (see figure 3.1). Every participant was an actor in the scenario. The hope was to play various scenarios and condense a process based on traces of the interactions at the table. Therefore we tried different media, different communication channels and different objectives during the play. After each prototype, we collected feedback in a moderated discussion from the participants. More details on these initial prototypes have been published separately [81].

**Shortcomings of role-playing prototypes.** Throughout all prototypes, participants reported that they enjoyed engaging with the play. The participants were highly motivated to evolve the setting beyond the initial descriptions. The banks created new loan products, suppliers formed new alliances and shops changed their business model from selling to leasing.

What was fun for the participants was a challenge for us as designers of such a process elicitation technique. People loved to bend the rules and asked for a game
3. Building the TBPM toolkit

Figure 3.1. Role-play prototyping with Lego and Post-Its (left). Specialized stickers and plates were used (right) to examine the applicability of channeled communication in role-playing setups.

master to argue with and to guide them through the play. But playing out the process had more fundamental challenges:

- **Interactions, not a process model:** To come from a role-play to a process model, we wanted to trace interactions on the table and transform them into a process model. We tried various approaches to channel the communication for better traceability. The stricter the rules on interactions, the more likely the rules were ignored. We could not derive a comprehensive process model from the artifacts created. Yet even then, the process model would have been created only after the workshop, not during the discussion and therefore not by the participants.

- **State of discussion needs representation:** People tended to fade in and out of discussions at the table. This was due to today’s ubiquity of mobile devices, side talks to peers, or simply daydreaming. When they faded back into the discussion, they needed a way to catch up to the current topic. Thus, the state of the discussion needs to be represented at the table. This is strongly related to the traceability of interactions which we also struggled with at that point.

- **Many objects, unclear semantics:** We prototyped with various materials including colored Post-Its, stickers, wooden-tablets and Lego. Participants knew the objects but their semantics was special for the role-playing session. Frequently, people reinterpreted the meaning of objects. They assigned new semantics to existing objects or introduced new objects with special semantics that were not well communicated. This led to confusion about the meaning of objects on the table.

**New direction with first tangible objects.** New input from outside steered the investigations into a new direction. Jonathan Edelman, a visiting researcher from Stanford University, brought acrylic shapes into the prototyping process. Originally, he wanted to support the search for communication channels to steer the
3.1. Initial prototyping

interactions in role-playing games. While discussing the current struggles, we decided to test the shapes as process modeling shapes instead of communication channels. This new tooling addressed the shortcomings discussed above as follows:

- **Immediate process representation**: Instead of tracing interactions at the table and creating a process model afterwards, participants directly create a process model, the desired result.

- **Model reflects state of discussion**: The evolving model represents the state of the discussion. People fading in and out can see where something happened and decide whether it is relevant to them.

- **Limited set of specialized objects**: The acrylic shapes are specialized objects with specific semantics. They are predefined and it is not possible to create new ones spontaneously.

**Testing with tangible objects.** To prototype the idea of tangible modeling, we contacted administrative assistants at Hasso-Plattner-Institute, University of Potsdam. We conducted three interviews in which we asked them to describe common processes, such as travel booking or accommodation for faculty members visiting a conference. One interviewer tried to create the process in front of the interviewee during the interview using the acrylic shapes.

We found that the acrylic shapes (see figure 3.2, left) worked well as a shared object that the interviewee and interviewer could talk about. Stepwise unfolding the process allowed the interviewee to follow the act of knowledge capturing and to contribute. After some time, the interviewees took the dry erase pen and started correcting information in the model or even extending it (see figure 3.2, right). We saw the potential of the acrylic shapes as an easily accessible tool for people to engage with their process models.

![Figure 3.2. First acrylic shapes (left) and the first mapping situation with administrative staff at Potsdam University (right).](image)

Yet, shapes used in these prototypes did not reflect a process modeling language. This was a limitation as we could not frame all the knowledge into the concepts given in process modeling languages. We concluded that, given a full modeling
3. Building the TBPM toolkit

language in acrylic, domain experts could possibly map and frame proper process models themselves. This led to the creation of the first tangible business process modeling toolkit.

3.2. The tangible business process modeling toolkit

The tangible business process modeling (TBPM) toolkit is a set of shapes reflecting four basic icons of the Business Process Modeling Notation (BPMN) [56]. The concepts embodied in shapes are activities, events, gateways, and data objects (see figure 3.3). We choose BPMN because it is a rising standard for process modeling and a sophisticated modeling notation [149].

Shape semantics. Activities represent the work performed by a person or a software system. Events are used to mark start- and end-point of the process. Furthermore, events may be used to make the process flow wait for something or specify the reaction to error behavior. Gateways are used to split and join the process flow with different semantics. As examples, they can be used to create alternative or parallel process paths. Data objects represent information, such as emails or documents, processed in the process. The shapes can be inscribed with a dry erase pen. These pens are designed to work with whiteboards but work with the TBPM toolkit as well. By writing on the shapes it is possible to represent almost all of the over fifty process modeling shapes specified in the BPMN 2.0 standard [56]. The missing information, namely the order of activities and association arrows, can be drawn directly on the table. The same is true for swimlanes that capture responsibilities. A swimlane defines a role, in other words, a resource that performs all activities in the corresponding swimlane. Thus, the TBPM toolkit can be used to create process models, conform to the BPMN standard [56] and without losing expressiveness. The material and size of the shapes was chosen to provide a comfortable haptic experience based on the feedback that we received on the first tangible objects. Each shape is about six millimeters thick. An event shape is ten centimeters, about four inches, in diameter. An activity shape is about seventeen centimeters in diameter, about the size of a post-card.

![Figure 3.3. TBPM toolkit - A set of writable acrylic shapes reflecting the BPMN iconography. From left to right: event, activity, data object, and gateway. It can be used to create BPMN conform models on a table top.](image-url)
3.2. The tangible business process modeling toolkit

Use of the toolkit. The toolkit is designed to be used on a conference table, with at least 1.5 by 3 meters (about thirteen feet in diameter). The participants stand around the table and map out the information. In figure 3.4 we depict a TBPM process model in four phases of creation. In the first phase, start and end of the process are determined. They are named as the start and end event of the process. Then the main activities are mapped. They are loosely arranged from left to right to indicate an order relation. Arrows are not drawn at this stage to keep the shapes floating on the table. After the main activities are mapped the process is stepwise enriched with gateways, documents, and role information. Finally, it is refined to a proper process model including arrows. At that stage it does not differ from a formal BPMN process model created with conventional software modeling tools.

![Figure 3.4](image)

**Figure 3.4.** A TBPM process model in four phases of modeling. First, people (1) decide on start and end-point of the process, (2) afterwards they map main activities, (3) enrich and refine process information until they have created (4) a formally valid process model.

The business process modeling (BPM) expert acts as a moderator and facilitator. He guides the group that creates the process model. In the terminology of the role-play, he is the game master. He supervises that the participants do not break the rules of process modeling. In particular, he has to (re-)explain process modeling concepts as needed and ensures that they are not misused. Thus, all participants shall understand the model, can review and refine it.

Revisiting principles derived from cognitive science and design research. From literature research in chapter 2 we formed principles for modeling with non-professional modelers derived from cognitive science and design research. We revisit these principles here and illustrate how they are addressed by the TBPM toolkit.

- **Map out information:** The process is externalized stepwise into a model reducing the amount of information to be kept in the brain. This reduces
the cognitive load of the participants and also adds dimensional stimuli to better remember information.

- **Choose an expressive representation:** Assuming that the BPMN language is a suitable and expressive representation for process modeling [149], we transfer that expressiveness to the tangible toolkit. The matter of discussion has an explicit process model representation. The representation is the same like the notation used for later analysis, improvement discussions, or process automation.

- **Make it intuitive to use:** The interaction concepts required to use the tangible toolkit have been trained since kindergarten. Thus, there is no new knowledge to be learned in order to interact with it. This frees cognitive capacity, especially for non-professional modelers, such as domain experts, which can concentrate on the actual modeling task.

- **Fit media with model purpose:** The media chosen, thick acrylic shapes, afford inscriptions and correction using dry erase markers. The colorful and large shapes transport a playful nature and remind of children’s toys. These qualities lower the barrier to interact and engage with the process models. The specialized objects support a precise discussion with specific semantics associated with the shapes.

**Iterations of toolkit and method.** The development and refinement of the tangible toolkit and application method were part of the research journey. This section has given a condensed overview of the result from multiple iterations. The next sections of this chapter show preliminary versions of the TBPM modeling technique. The method and tool co-developed with the ongoing research.

### 3.3. Study 1: university assistants using TBPM, Post-Its, or structured interviews

**Setting.** We asked six administrative assistants (called subjects here) at Stanford University and Potsdam University to report on their processes such as making travel arrangements for the professors that they work for. The study was conducted to investigate how TBPM can be introduced in interviews and how it is different to other interview situations. Three types of process elicitation were conducted with the five subjects. We asked the first three subjects to talk about their processes in a (1) structured interview or (2) while modeling their process using TBPM. Later, we also added (3) Post-Its as an alternative way to externalize knowledge during process elicitation. In total, twelve elicitation sessions were conducted with five university assistants.

For each elicitation session we followed the same catalogue of questions. It started with questions to get an overview of the process. Afterwards, interviewees were asked to elaborate on each step of the process and subsequently asked what they like or dislike about the current process. The elicitation sessions concluded
by asking the subjects whether there is anything else that they would like to share about the process.

**Observations with interviews and Post-Its.** We observed that in structured interviews, the subjects started by telling a compact narrative, i.e. a quick run through the process. Subjects with more experience spoke more quickly and more structured about their process with a higher degree of generalization. When asked to dive deeper into the steps of the process, the subjects often referred to individual cases. For structured interviews, subjects were not provided with any memory aid. In one instance one subject used her fingers to count and hold on to the abstract steps to be done (see figure 3.5, left). The average structured interview took about ten minutes.

We conducted two elicitation sessions in the same way but offered Post-Its as a way to map information during the elicitation. We encouraged the interviewee to use the Post-Its as they saw fit. The result was a stream of Post-Its marking points in the narrative. We observed that mapping process-related information to Post-Its was straightforward because every thought was mapped without reflection. In the two elicitation sessions conducted with Post-Its, the resulting streams of Post-Its captured mixed information types such as events, activities, hand-overs, artifacts, and additional annotations. There was no semantic distinction into different concepts. When asked to elaborate about the details the interviewees reproduced the narrative adding very little new information to the initially mapped story (see figure 3.5, middle).

![Figure 3.5](image.png)

Figure 3.5. One subject in three different interview situations: In structured interviews only hands were available to hold on to information (left); Post-Its in interviews provided a mapping tool for the narrative told (middle); TBPM (right) provided a tool to frame the knowledge as a process model.

When asked the final question, "Is there anything else you would like to share?" subjects read the narrative from the Post-Its again but added no further information. The interviewees reported that they found it quite helpful to use Post-Its as a memory aid. One reported that any piece of paper would have done the same. In any case, the result of such the elicitation session was not framed into the concepts known in process modeling. The two elicitation sessions with Post-Its took twelve and fifteen minutes.
Observations with TBPM. When using TBPM we negotiated start- and end-point of the process first. We explained the concept of activities as work items and swimlanes to determine responsibilities. Afterwards, the tool was handed to the subject. Intuitively, subjects accepted a logical order if steps were laid out from left to right. During the elicitation session further concepts were explained where required.

We chose not to introduce the concept of control flow because all subjects naturally indicated the order by putting shapes from left to right. In four of five TBPM sessions, interviewees captured alternatives and parallelism by putting activities one over another. Only in one situation, both concepts occurred together and we introduced the gateways for exclusive and parallel routing in the process. In general, we found that very few concepts already added a lot of structure to the process elicitation discussion.

The initial process model creation with TBPM was relatively slow because subjects had to find appropriate activity names and write them down on the TBPM shapes. Once the process was modeled, it functioned as a map on which subjects navigated confidently. We observed subjects jumping around the process model in contrast to the linear narratives that were told in other interview types. They decided to add details and rearrange objects. Pointing at elements made it easy the interviewer to follow explanations. At that time, interviewees were sitting at the table. On average the TBPM interviews took twenty-eight minutes.

Lessons learned. Compared to structured interviews, process elicitation with TBPM and Post-Its enabled the subjects to review their initial statements. Post-Its create a stream of unclassified information, just like a narrative. When reviewing, the narrative is repeated from the stream of Post-Its but not reflected. This is different with TBPM. By introducing a small set of concepts, a structure was created. It functioned as a map that subjects navigated and iterated.

3.4. Study 2: IT students modeling computer setup

Setting. We invited ten freshmen in IT Systems Engineering (called subjects here) at the start of the semester to participate in an experiment pilot. The students were randomly assigned to do either an interview or TBPM modeling. This experiment pilot was conducted to learn how TBPM might be compared to other approaches. We learned about video coding standards and new process understandability test [88]. We also used this as an exploratory study to draw more insights and improve our understanding of the TBPM technique.

At the beginning, all students were given a brief introduction to BPMN as a modeling notation by means of a printed example process and subsequently did a pre-test. All participants scored well in the pre-test, indicating that they understood the fundamentals of BPMN as a modeling notation. The experimental task concerned setting up a windows PC for their grandparents. After the interview, a post-test on process model understanding was performed similar to the pre-test.
Both tests were based on a preliminary process understandability framework by Melcher et al. [88].

**Observations: Interviews vs. TBPM.** The test results did not indicate a difference in process model understanding due to TBPM modeling. Consistent with the previous study, the TBPM-driven interviews took thirty minutes on average while structured interviews took about ten minutes. In a thirty minute TBPM session, an average of five minutes were spent without a word or an action. The subjects were observed to look at the represented model and presumably think about the process and its details. While it is uncomfortable to be quiet in an interview situation, pauses from talking were acceptable in TBPM sessions.

![Figure 3.6](image)

**Figure 3.6.** University freshmen applying TBPM: Modeling made people spend more time thinking about and reviewing the actual process in contrast to structured interviews.

We used a big table to provide enough space (see figure 3.6). It made students stand up and walk. Standing created a dynamic and productive atmosphere. After the initial mapping, students were asked to name documents in the process, to identify problems and phases. In TBPM sessions each question triggered a refinement of the laid out process model. Subjects using TBPM constantly reviewed their model, applied changes and added information to it. In contrary, structured interviews made students quickly answer each question and move on.

As observed in study 1, mapping information with TBPM allowed participants to point to individual elements and locate the discussion in the process model. In contrast, subjects in structured interviews told inconsistent narratives. Precisely, they raised issues that were not followed-up on or forgot to elaborate on steps mentioned earlier. This happened less often in modeling sessions. We conclude that things are less likely to be forgotten if the information is laid out on the table.

After the initial process mapping, subjects were asked to identify independent activities, so that they could be performed in parallel with other activities. Subjects in structured interviews responded by enumerating tasks with loose interdependencies. Subjects using TBPM dramatically rearranged their process model to indicate options for parallelism.

**Lessons learned.** This time, the TBPM subjects were standing at a large table. It created a more productive atmosphere compared to structured interviews where
people were sitting. Subjects took more time for TBPM modeling than for interviews which was expected due to the overhead of modeling on top of talking. Subjects also took more time to think about the information they have mapped with TBPM. Once a process was modeled on the table, it functioned as a map for the interviewees to navigate in the process. The questions by the interviewers provoked subjects to review their process model, make corrections, or even totally rearrange the shapes on the table. It seems that TBPM mappings afford reviews and changes.

We failed to measure an improved process understanding being built up from using TBPM. Before and after the task, the IT students scored high with the understandability test that was used. We have done further investigations (published separately [53]), which indicate that modeling with TBPM may not increase the formal process modeling understanding. We know now that the investigations about process understandability in this experimental setup had significant limitations, which would make it unsuitable for a hypothesis validation experiment:

- **Immature test**: The understandability test used by us was published two months earlier at a scientific conference [88]. It builds on questions about execution semantics in a given process, such as ‘Can A and B be performed in the same instance of a process.’ There was discourse about its usefulness and – one year later – an experiment [73] that made the case for more fundamental research in that area. By now, a new research stream has started [40] towards a demystification of process understanding as a cognitive task with the long-term goal to design suitable understandability tests.

- **Pre-conditioned subjects**: Subjects reported in post-experiment interviews that they linked the basic concepts of process modeling (flow/AND/OR) to knowledge gained in other areas, such as circuit diagrams in physics. This partially explains the good test results. It also raises the question, whether people with a less formal background would perform alike with TBPM. Software engineering students (even freshmen) may not be good proxies for the domain experts that are the anticipated users of the TBPM technique.

### 3.5. Study 3: hospital doctors modeling clinical pathways

**Setting.** A German university hospital decided to use a process-oriented view to manage their clinical pathways. These are the processes that patients go through in hospital treatment for a specific disease. An experienced BPM consultant (here the BPM expert) was hired for a two-week full-time workshop to model and optimize processes with the hospital doctors. Upon invitation by the consultant, we sent an observer to bring in the TBPM toolkit and document the use of it. This was framed as a case study to explore how TBPM can be adopted in real projects with groups of people.

**Observations: First steps.** The first day started with a general introduction to Business Process Management and BPMN as a modeling language. On the
second day, the consultant started mapping the processes with the input from two student doctors and the medical superintendent. Within the first hour, the doctors started to engage in modeling their process. A rich set of process modeling concepts was used right away, including exclusive and parallel routing (gateways), responsibilities (swimlanes) and processed information (data objects). Nevertheless, doctors who occasionally dropped in also commented, ordered, and changed process steps although they had not participated in the first day introduction to BPMN. There was a strong notion of shared model ownership that allowed everybody to interact with the model and contribute their knowledge. The model was constantly discussed, changed, and refined while it was created (see figure 3.7). As the model grew, more tables were moved together to extend the modeling space. The result of the first day with TBPM was a detailed model depicting the two predefined core processes because they had much more in common than originally anticipated, they were captured in a single model at first. Divergences between the processes were captured using differently colored inscriptions.

**Observations: A mix of tools.** Overnight, the model was digitalized by the consultant and printed for a review discussion on the next day. This is a common practice but usually involves the translation of workshop results, such as Post-Its and notes, into process models. Instead, the pre-modeled process was photographed and reproduced using a software modeling tool. The next day was spent on a review of the initial process. Changes were applied to the model on the table using the TBPM toolkit. The consultant digitalized changes immediately. The forth day was spent on exploring and mapping some of the subprocesses using TBPM.

![Figure 3.7. TBPM applied for clinical pathway modeling: the generative nature and shared model ownership made TBPM the tool of choice for joint model creation.](image)

By day five, more than twenty process models depicted both clinical pathways, including overview pictures, processes, and subprocesses. The doctors were introduced to the software tool and used it to browse through the captured process
knowledge and enrich the models with more information. Discussions about existing process models were usually held with printouts or at the computer. Having multiple embodiments of a process model, e.g. in TBPM, on paper, and in software, created many options to introduce changes. Combined with diverging discussions, it was sometimes unclear which process model embodiment was the most current one and which changes were approved already approved by the whole group. After the fifth day, the TBPM case study ended, but the project went on for another five days to validate and refine the clinical pathway models.

**Interview feedback.** In interviews after day five, the doctors reported that it was fun to work with the TBPM toolkit. They said it was well accessible and therefore suited to integrate everybody. The doctors also said they preferred paper print-outs for model reviews. The modeling software was perceived as a way to store and browse models. Tangible modeling was perceived as the optimal way to jointly develop new models. Yet, the amount of different media was overwhelming. In some situations, it was not clear which media should be used and which model version is the most recent. They asked for guidance by the BPM consultant.

The BPM consultant did not anticipate that TBPM would allow jump-starting initial process mapping as it did. He estimated an increase in productivity of thirty percent for the first three to five days. For future workshops he would like to stay at the table for all process mappings and reviews, and try to avoid ‘fiddling with the [software] tool’ during the workshop hours. He said that each tool should have a clear purpose. In his opinion, the most important difference between TBPM and standard process elicitation is that TBPM forces the participants to work out their processes themselves, instead of leaving the participants in the backseat of process modeling sessions. He would recommend TBPM for highly complex processes that require a lot of discussion. He also pointed out some aspects that accelerate the use of TBPM. As an example, instead of drawing the control flow on the table right away, he recommended postponing this until the very last moment. Thus, the model can be changed more easily during creation.

**Lessons learned.** We conclude that TBPM is applicable for group modeling sessions. It fits into the niche of joint model creation in workshops. The intuitive handling enables all participants to contribute, even people dropping in occasionally. This created a strong notion of shared ownership. The toolkit has to interplay with other tools such as software and print-outs which are more suited for knowledge browsing. Therefore guidance is needed on when and how to use the toolkit.

3.6. Summary of Findings from prototypes and exploratory studies

The journey started with the idea to make process modeling a group experience and the research question how this may be possible. At first, we prototyped role-playing games (see section 3.1 and [81]). We found that they are fun to do but it is hard to trace a process from the interactions. We identified the need to
3.6. Summary of Findings from prototypes and exploratory studies

(1) have a limited set of objects with well-defined semantics, (2) to represent the state of the discussions at the table, and (3) make the created artifact a process model instead of translating it from observed interactions. When we first used transcribable acrylic tiles to facilitate interviews, we saw the potential to address the aforementioned needs by creating the TBPM toolkit. It seemed to be one possible answer to the research question.

TBPM toolkit and experiences. The TBPM toolkit is a set of shapes that reflect the basic BPMN iconography. The processes are created on a table using the TBPM toolkit and dry erase markers. The created models can be BPMN [56] standard compliant with no loss of expressiveness.

We tested the TBPM toolkit in exploratory studies with office assistants, freshmen IT students, and physicians. From these studies we took away the following key insights:

- **Concepts create structure:** Interviews elicit narratives. Interviewees tell stories but the interviewer has to filter and frame the information into the concepts important for the process model. Mapping itself does not help to filter and frame as we saw with Post-Its in study 1. In the same study, the TBPM toolkit structured the knowledge by introducing a small set of concepts: activities, start/end-point, and responsibilities.

- **Standing creates productive atmosphere:** Many meetings are held while sitting. In study 2, participants stood at the table for practical reasons. We learned that it makes a huge difference to the atmosphere in the workshops as people standing are much more active.

- **Structure enables navigation:** In all studies we observed participants navigating in the mapped process model. This applied to the interviewee and the interviewer alike. The model is a map in which people can locate a discussion, e.g. through pointing at a shape.

- **More time thinking:** In study 2, we compared interviews with TBPM modeling and noticed dramatically more time spent thinking during modeling sessions. Pausing and thinking seems more acceptable in TBPM sessions. The purpose of an interview is talking and the focus is on people. In TBPM sessions the focus is on the model.

- **More reviews and corrections:** We noticed more reviews and corrections of the TBPM process model, in particular, when comparing interviews with TBPM modeling in study 2. We noticed people totally rearranging models even towards the end of the mapping session.

- **TBPM fits a niche in the ecosystem:** When applying TBPM in a real scenario in study 3, we learned that the tool fits a niche within a larger ecosystem of tools. TBPM is well suited for process model creation. The process model gets digitalized using software afterwards. The digital models can be shared, printed and versioned. TBPM has to fit in the ecosystem and relate to the existing tools.
3. Building the TBPM toolkit

☐ **Guidance needed:** Already the first role-playing prototypes called for a game master, a person that knows the rules and can carry the discussion forward. In real projects this is the BPM expert who acts as a facilitator for TBPM sessions, such as in study 3. However, this person may also need guidance on how to facilitate TBPM sessions.

**More research needed.** The preliminary findings presented above are first steps towards the goals for our research, in particular, towards the goal to create a group experience. But we also made first steps towards the comparison with other techniques and towards evaluating the applicability in practice. Yet, these are preliminary findings. We take them as inspiration and obligation for more research in the following chapters.

In chapter 4, we run a controlled experiment to quantify the differences between interviews and TBPM modeling. The research in chapter 5 is devoted to the applicability in practice. There we develop guidance and compare TBPM with established workshop practices.
4. Controlled experiment with individuals

We have the goal to compare our solution to existing elicitation approaches. In chapter 3, we observed differences between people giving interviews and people applying TBPM modeling. We assumed these effects have been caused by the TBPM toolkit. This chapter presents an experiment to assess hypotheses about the effects of TBPM modeling.

The experiment is focused on individuals in a laboratory environment to minimize unintended influences, in other words, additional differences in the setting of the groups compared. Those additional influences could weaken the conclusion that an effect was caused by the treatment because, strictly speaking, one can only observe co-occurrences of treatment and effect.

The setup and execution of this experiment was guided by literature from Creswell [24] and Wohlin et al. [150]. We used literature from experimental software engineering [66] and statistics [39] to inform the structure of this chapter and the level of reporting.

This experiment was set up with fourteen hypotheses in total and results were published with different level of detail and focus [83, 53, 84, 86]. This chapter concentrates on nine hypotheses with the strongest contribution to understanding TBPM as a tool.

4.1. Experiment planning

We outline the planning activities conducted before the experiment in this section. We start by deriving hypotheses from our goal. Afterwards, we outline the experiment setup, the measurement instruments for the hypotheses and the analysis procedures.
4. Controlled experiment with individuals

4.1.1. Goal and hypotheses

Our goal is to understand and quantify the benefits of using TBPM in comparison to other techniques. Therefore, we compare tangible business process modeling to structured interviews. In essence, we think that TBPM leads to more effective elicitation.

**Defining effective elicitation.** Structured interviews have been named the most effective requirements elicitation technique so far [27]. The word ‘effective’ means that something produces the ‘desired or intended result’ [129]. In the studies examined in [27] (see also section 2.1) the techniques are mainly compared by the amount of information that they elicit. In other words, more information is seen as more effective.

We think that the concept of ‘effective elicitation’ needs adoption for business process modeling. For example, a process model is the desired result of process elicitation sessions. In contrast to interviews, the TBPM session produces a process model as the direct result of the session. Therefore, one could argue that TBPM is more efficient already. We opt to test two other fundamental aspects derived from our research objective: engaged users and validated results.

**User engagement.** TBPM uses tangible media which is seen as a key factor for task engagement, e.g. in HCI research [65]. In those cases, engagement is measured as the time people are activated to work on a problem, e.g. by Xie et al. [152]. We have already observed in section 3.4 that people take more time for TBPM sessions. We think that they are more activated to work on their process. Engagement as a concept can explain this phenomena.

Since tangible modeling consumes time to handle the tool itself (e.g. writing on tiles), we split up the observed time into more fine granular observations. We hypothesize that people spent more time talking ($H_1$) about the process but also spent more time to think ($H_2$) about what they do. We get more concrete when we operationalize the measurement of the hypotheses in section 4.1.5.

From another perspective, Schaufeli defines engagement as the dimensions of activation and identification [120]. Activation was already discussed as the time spent on the task. On top, we want to ask people for their feelings about it and hypothesize that people also have more fun ($H_3$) with TBPM modeling as a further aspect of activation. The dimension of identification is seen as the degree to which people emotionally relate to something [120], in our case the created process model. That leads us to hypothesize that people modeling with TBPM have more motivation ($H_4$) to accomplish the task and are more committed to the solution ($H_5$) that they shaped. Figure 4.1 visualizes how we refine our model towards the hypotheses.

**Validated results.** Validation stems from feedback on existing artifacts. In current situations, the result – the process model – is created after the elicitation with the client. Schneider [122] points out that validation cycles with the client are a time consuming aspect of requirements elicitation projects. That is based on the
Figure 4.1. The idea of effective elicitation decomposed into nine hypotheses. We decided for user engagement and validated results as desired (effective) outcomes. Fine granular aspects and measurement instruments are retrieved from literature.
assumption that the artifact is build after the discussion with the client and an additional validation meeting is held. He proposes to create the artifact during the elicitation to trigger instant feedback and speed up validation. This is the intention of TBPM. Validation cycles are characterized by reviews and adjustments to the model. We hypothesize that people do more reviews \((H_6)\) when using TBPM and apply more corrections \((H_7)\) to their process model. We already observed this behavior in the explorative study conducted in section 3.4.

Frederiks [41] proposes that users validate models by deciding on the significance of information. In model building significance, of information is a design choice. We propose that this is based on a clear understanding of the modeling goal. We hypothesize that TBPM provides a clear fifteen-item goal \((H_8)\) for the elicitation session. Frederiks [41] also proposes that validation depends on the competencies of subjects. Validation relies on a deep understanding for the topic. We hypothesize that TBPM creates more process understanding \((H_9)\) that in turn supports the validation process.

We note that the hypotheses are not a forced consequence of the identified aspects and their building involved interpretation. We discuss this decomposition when assessing the measurement validity in section 4.3.3.

4.1.2. Experiment setup

We design the following experiment, as shown in figure 4.2. The participants (called subjects here) first get conditioned to a certain level of BPM understanding. Therefore we use a two page introduction and a sample model that explains how to cook a pasta dish. After conditioning, subjects are randomly assigned to either be interviewed or model with TBPM. The topic is randomly chosen between buying expensive equipment and running a call for tender. A structured questionnaire guides the experimenter through the experimental task. Two experimenters operate the experiment. One guides the subjects in the role of an interviewer, the other experimenter observes the situation and ensures a stable treatment throughout the experiment. They randomly swap roles.

order, which means all During the experimental task data is collected using video recording. Afterwards, a fifteen-item questionnaire is to be filled in by the subjects. In every step of the experiment, the time is tracked but not constrained. After the first run, subjects rerun the experimental task using the other elicitation method and do the questionnaire the second time.

This experiment setup is called a ‘randomized balanced single factor design with repeated measurements’ [150] also known as a ‘within-subjects design’ [50]. All subjects get both treatments assigned in different order, which means all subjects get interviewed and perform TBPM modeling. Finally, all subjects are rewarded for their participation with a chocolate bar and a cinema voucher.
4.1. Experiment planning

Figure 4.2. The experiment setup visualized: All subjects get conditioned first and afterwards they get both treatments in random order (within-subjects design). Data is collected using video recording and questionnaires.

4.1.3. Experimental material

We outline and explain the printed experimental material here. The original documents are appended to this thesis (see appendix A.5-10). The experimental material is in German.


- **Sample model**: A one page document that depicts the process of ‘Making Pasta’. It also contains a legend of the BPMN elements used and four pragmatical hints on process modeling. In particular, it suggests the balanced use of gateways, an eighty percent rule for relevance to set granularity, verb-object style activity labeling as suggested by Mendling et al. [92] and a notational convention for conditions at gateways. The document can be found in appendix A.7.

- **Task sheet**: One paragraph explaining the experimental task. Subjects are asked to model or report on one of the following processes: buying a new flat screen for the entrance to the company building or running a call for tenders to build a new warehouse. The introduction sets the context, the
4. Controlled experiment with individuals

start-point and the end-point of the process. The task sheets can be found in appendix A.8.

- **Interview guide (for experimenter):** Experimenters guide through the modeling and interview task by asking the same six questions in the same order. It starts with ‘Please identify all relevant steps’, and concludes with ‘Is there anything else you want to tell us about the process?’. Experimenters read out the exact questions from the interview guide. Additionally, it contains standardized answers to questions from subjects, such as ‘Make an assumption and proceed from there’. The interview guide can be found in appendix A.9.

- **Questionnaire:** A questionnaire with fifteen questions to be rated on a 5-point Likert scale. Three questions operationalize one hypothesis. We detail the hypothesis operationalization in section 4.1.5. The questionnaire can be found in appendix A.10.

4.1.4. Subject selection

In explorative study 2 (see section 3.4), we learned that freshmen engineering students have a formal background that enables them to perform extraordinarily good in process modeling and understanding. Thus, subject selection is a crucial aspect. The sample population used in research studies should be representatives of the population to which the researchers wish to generalize [22, 150]. Thus, we want potential users of TBPM to participate in the experiment. We see clerks and managers, the domain experts, as the potential users of the TBPM tool. Hence, we looked for clerks as subjects in this experiment.

We got the opportunity to run an on-site experiment at a trade school in Potsdam (Germany) with graduate office and industrial clerk students (19-21 years old). They all work in companies and study part time at the trade school. Industrial clerks do planning, execution, and controlling of business activities. Office clerks perform supporting activities in a department, e.g. as office managers. On the job, both professions might overlap depending on the size of the company. Both groups might be questioned in process-oriented projects by BPM experts. In other words, they represent the target population that we like to address with TBPM.

4.1.5. Hypotheses operationalization

We refine the hypotheses presented in section 4.1.1 to be measurable in the experiment design presented in figure 4.2. We do this by means of a questionnaire and video analysis. We operationalize each hypothesis as $H_x$ and its null hypothesis as $H_{0x}$. The null hypothesis describes a counter position in which no effect is to be expected. If the difference between the groups is significant (see section 4.1.7 for details) we reject the null hypothesis in section 4.4 which is equivalent to accepting a difference as proposed by the hypothesis.
Questionnaire-based hypotheses \((H_3,H_4,H_5,H_8,H_9)\). Hypotheses which rely on perceived measures are tested using a questionnaire. On a five-point Likert scale subjects rate their agreement to, in summary, eighteen statements. Each hypothesis is tested by presenting three statements. The questionnaire was designed to test six hypotheses of which five are discussed here. For each hypothesis, two statements are formulated towards the expected effect, one is negatively formulated. The order of questions was randomized for the questionnaire. The level of agreement is mapped to the values one to five where one is no agreement and five is a strong agreement. The values are aggregated (negative statements are turned around by calculating \(6 - \text{value}\)) to retrieve the actual value to work with. The hypothesis holds if there is a statistically significant difference according to the method immediately used before, TBPM or interviews. More formally, we define the hypotheses as follows:

- \(Q = (q_1, \ldots, q_{18})\), i.e. the sequence of statements in the questionnaire
- \(p : Q \rightarrow [1, 2, 3, 4, 5]\), i.e. the mapping function that assigns a value to a statement from the questionnaire
- \(P = p_1, \ldots, p_n\), i.e. the set of all mapping functions (one per filled-in questionnaire)
- \(P = P_{tbpm} \cup P_{int}; P_{tbpm} \cap P_{int} = \emptyset\), i.e. each set of statements is either from an interview or TBPM group
- \(h := \mathcal{P}(P) \times Q \times Q = \mathcal{P}(P) \times Q^3\), i.e. an hypothesis is evaluated based on a set of mappings and three statements.
- \(h(P, x, y, z) = \frac{\sum_{p \in P} p(x)+p(y)+(6-p(z))}{3|P|}\), i.e. for a set of mappings and three statements, we calculate an average value according to the conventions.

To calculate the average per hypothesis we define function \(h\), as shown above. As input, it takes a set of mappings (filled-in questionnaires) and three questions that should be aggregated to represent the value for one hypothesis. By convention, the last variable \(z\) is always the negatively wired statement from the questionnaire. The sequence of statements \((q_1, \ldots, q_{18})\) reflect eighteen items in the questionnaire of which fifteen have been evaluated for the five hypotheses tested here. The original questionnaire is appended to this thesis in A.10. The questionnaire items are combined for hypothesis testing as follows:

- \(H_3: h(P_{tbpm}, 2, 14, 18) > h(P_{int}, 2, 14, 18)\), i.e. subjects report more fun in TBPM sessions than in interviews.
- \(H_{03}: h(P_{tbpm}, 2, 14, 18) \not> h(P_{int}, 2, 14, 18)\), i.e. subjects report not more fun in TBPM sessions.
- \(H_4: h(P_{tbpm}, 4, 11, 7) > h(P_{int}, 4, 11, 7)\), i.e. subjects report to be more motivated in TBPM sessions than in interviews.
- \(H_{04}: h(P_{tbpm}, 4, 11, 7) \not> h(P_{int}, 4, 11, 7)\), i.e. subjects report not more motivation in TBPM sessions.
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- $H_5$: $h(P_{tbpm}, 13, 17, 5) > h(P_{int}, 13, 17, 5)$, i.e. subjects report to be more committed to the solution created in TBPM sessions than in interviews.
- $H_{05}$: $h(P_{tbpm}, 13, 17, 5) \neq h(P_{int}, 13, 17, 5)$, i.e. subjects report not to be more committed to the solution created in TBPM sessions.

- $H_8$: $h(P_{tbpm}, 6, 8, 15) > h(P_{int}, 6, 8, 15)$, i.e. subjects report a clearer goal understanding for TBPM sessions than for interviews.
- $H_{08}$: $h(P_{tbpm}, 6, 8, 15) \neq h(P_{int}, 6, 8, 15)$, i.e. subjects report no clearer goal understanding for TBPM sessions.

- $H_9$: $h(P_{tbpm}, 9, 12, 3) > h(P_{int}, 9, 12, 3)$, i.e. subjects report to have gained more process understanding from TBPM sessions than from interviews.
- $H_{09}$: $h(P_{tbpm}, 9, 12, 3) \neq h(P_{int}, 9, 12, 3)$, i.e. subjects report to have gained no more process understanding from TBPM sessions.

**Video hypotheses ($H_1$,$H_2$,$H_6$,$H_7$).** We operationalize hypotheses related to time and actions taken during the experimental task using video analysis. We define the following video coding schemes:

- **Time Slicing**($H_1$,$H_2$): The duration of the experimental task is sliced to belong exclusively into one of five categories. We define a category for the (1) use of TBPM ($use_{tbpm}$) such as labeling and positioning the shapes without talking, we define (2) $talk_{tbpm/int}$ as the time people talk about the process, (3) $usetalk_{tbpm}$ is talking and using TBPM (to avoid overlap between $use_{tbpm}$ and $talk_{tbpm}$). We define a code for the (4) time spent silent ($silence_{tbpm/int}$) when people do not talk and do not handle TBPM. Finally, (5) $rest_{tbpm/int}$ captures remaining time such as interactions with the interviewer. The same coding scheme is used for both experimental tasks. However, $use$ and $usetalk$ do not apply for interviews since there is no TBPM to use.

- **Corrections and Reviews**($H_6$,$H_7$): Both are coded as distinct events. We code $corrections_{tbpm/int}$ if the context of an already explained process part is explicitly changed. In TBPM sessions this involves relabeling or repositioning which impacts meaning of the process model. In interviews explicit revisions of previously stated information is considered a correction. The $reviews_{tbpm/int}$ are defined as events where subjects decide to recapitulate their process. This must involve talking about the process as we cannot account possibly silent reviews. This scheme is the same for both experimental tasks.

Using this coding scheme we operationalize the video hypotheses in the following way:

- $H_1$: $talk_{tbpm} + usetalk_{tbpm} > talk_{int}$, i.e. subjects talk more in TBPM sessions than in interviews.
  - $H_{01}$: $talk_{tbpm} + usetalk_{tbpm} \neq talk_{int}$, i.e. subjects don’t talk more in TBPM sessions.

- $H_2$: $silence_{tbpm} > silence_{int}$, i.e. subjects are more silent in TBPM sessions than in interviews.
  - $H_{02}$: $silence_{tbpm} \neq silence_{int}$, i.e. subjects are not more silent in TBPM sessions.
4.1. Experiment planning

- \( H_6: \text{reviews}_{tbpm} > \text{reviews}_{int} \), i.e. subjects make more reviews in TBPM sessions than in interviews.
  \( H_{06}: \text{reviews}_{tbpm} \not> \text{reviews}_{int} \), i.e. subjects don’t make more reviews in TBPM sessions.

- \( H_7: \text{corrections}_{tbpm} > \text{corrections}_{int} \), i.e. subjects make more corrections in TBPM sessions than in interviews.
  \( H_{07}: \text{corrections}_{tbpm} \not> \text{corrections}_{int} \), i.e. subjects don’t make more corrections in TBPM sessions.

4.1.6. Variables

The independent variable in this experiment setup is the method used for process elicitation. Subjects are either questioned in a structured interview or undergo the same questions while modeling their process with the tangible business process modeling toolkit. The dependent variables are formed from the data collected for hypothesis testing during and immediately after the experimental task. We use a notational convention for the data sets collected: \( \text{intention}^{V/Qx} \). As an example, \( talking_{V1} \) describes the set of talking times as measured with the video analysis \( (V) \) for hypothesis 1. Likewise, \( fun_{Q3} \) is the set of all ratings collected with the fun related questionnaire \( (Q) \) items for hypothesis 3.

4.1.7. Analysis procedures

Questionnaire data is analyzed by assigning a value [1..5] according to the agreement level per statement as indicated on the Likert scale, described in section 4.1.5. Video data is analyzed by two independent reviewers using the VCode [58] video analysis tool. The reviewers use the coding scheme specified in section 4.1.5. They compare their results and (if needed) resolve conflicts by negotiation. The average values (either amount or duration) of both reviewers after negotiation are used to perform the statistical analysis. All data is tested for normal distribution using Kolmogorov-Smirnov and Shapiro-Wilk test [39]. Normal distribution is an assumption for the further analysis techniques performed.

**One-way repeated-measures ANOVA.** The main hypothesis testing is done based on a one-way repeated-measures ANOVA (analysis of variances). It attributes the variances in the data set to differences between subjects and differences within subjects. From there, the differences within subjects caused by the independent variable are determined. This is done for each dependent variable. Figure 4.4 in section 4.3.4 visualizes this procedure. We use a significance level of \( p < .05 \) which corresponds to a probability of error of less than five percent. It means that the effect is expected in the real population (scaled from the sample size) with a probability of 95 percent. Five percent error probability is wide spread consent for a significance level in statistical analysis [24, 39, 66, 150].
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**T-test.** Additionally, we carry out a dependent student’s t-test. The student’s t-test assesses whether the means of the two treatment groups are statistically different from each other. The dependent t-test is suited for paired samples such as our data from the repeated-measurement design. We used it to get a different view on the data in section 4.3.4. The term ‘statistically different’ means that we calculate the probability of this difference being measured by chance. We use the acceptance level of p<.05 which is an error tolerance of five percent. This is widespread consent in statistical analysis [24, 39, 66, 150]. We also use the t-test in section 4.3.5 to assess potentially confounding factors for their relevance. They might have influenced the performance of the subjects without our intent. We assess the following potentially confounding factors:

- **Reported process:** Each subject reports on two different processes, buying a flat screen and running a call for proposals to build a new warehouse. Processes might be unbalanced.

- **1st-vs-2nd run:** Each subject goes through the treatment twice. Repetition effects such as learning might influence the performance of the subjects.

- **Experimenter:** Two experimenters are randomly assigned per subject to run the experiment (with both treatments). Interviewers directly interact with the subjects and might be influential on the outcome.

**Cronbach’s alpha and Cohen’s kappa.** In section 4.3.3 we assess the reliability of the measurement instruments. We use Cronbach’s alpha (α) to assess the questionnaire items. Cronbach’s alpha determines the internal consistency of the three questionnaire items that are used to operationalize one hypothesis. In other words, it indicates whether the three questions chosen measure the same underlying aspect.

The video data is analyzed by two independent reviewers. They compare their results and (if needed) resolve conflicts by negotiation. Cohen’s Kappa (κ) is used to determine the inter-rater agreement before negotiation to assess the quality of our coding guidelines.

**Principal component analysis.** We use a principal component analysis for validation of the hypothesis decomposition in section 4.3.3. This is a technique to determine sets of strongly correlating variables, which are approximated with one factor, the principal component [39]. Ideally, the dependent variables form two factors. Those that reflect the measures for user engagement and those measuring validated results.

4.2. Experiment execution and data collection

The experiment design was executed in December 2009 at a trade school in Potsdam. Slots were offered to the students by short teasers given in two classes on Monday morning. Students could choose to swap one lecture unit for experiment
participation (about one hour). The classes consisted of industrial clerks and office clerks at the age of nineteen to twenty-one. Seventeen of the twenty possible slots were taken by the students during the week. We tested with 7 office clerks and 10 industrial clerks.

Figure 4.3. Screenshots from the video as taped by the cameras during the experiment execution. The same subject being interviewed (left) and modeling with TBPM (right).

Each experiment run started with a short informal warm-up chat and afterwards followed the design as outlined in section 4.1.2. One experimenter ran the experiment, the other one operated the cameras and observed the situation to ensure a stable treatment. Figure 4.3 depicts the two experimental tasks as taped by the cameras. One videotaping went wrong, leading to a sample size of sixteen for the video-based hypotheses.

4.3. Data analysis

This section summarizes the data collected and reports on the statistical analysis of the results. The results are interpreted in section 4.4.

4.3.1. Descriptive statistics

From seventeen students in two runs, we collected 34 questionnaires with 510 statements in total. The video analysis was conducted based on 6,74 hours of video material. One TBPM session taping went wrong leading to N=16 for all hypotheses that rely on video analysis.

Table 4.1 describes the analyzed video data in terms of time slices determined and events detected. The numbers reported for the video duration and video slices are in minutes. The numbers for $corrections_{tbpm/int}$ and $reviews_{tbpm/int}$ report events.

TBPM sessions took twenty minutes (19.52) on average ranging from ten (10.25) to almost forty minutes (38.98). In comparison, interviews took about five minutes (5.42) on average ranging from three and a half (3.53) to almost ten minutes (9.68) at most. In the lower part of table 4.1 we depict the events coded during the video analysis for the $corrections_{tbpm/int}$ and $reviews_{tbpm/int}$ conducted. There
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<table>
<thead>
<tr>
<th>Data Type</th>
<th>N</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>video tbpm/int</td>
<td>16</td>
<td>19.52/5.42</td>
<td>10.25/3.53</td>
<td>38.98/9.68</td>
<td>8.22/1.97</td>
</tr>
<tr>
<td>talk tbpm/int</td>
<td>16</td>
<td>4.65/3.43</td>
<td>2.62/2.05</td>
<td>10.88/6.60</td>
<td>2.32/1.27</td>
</tr>
<tr>
<td>silence tbpm/int</td>
<td>16</td>
<td>5.54/0.94</td>
<td>1.25/0.27</td>
<td>16.58/2.38</td>
<td>3.86/0.67</td>
</tr>
<tr>
<td>use tbpm</td>
<td>16</td>
<td>4.60</td>
<td>1.91</td>
<td>9.86</td>
<td>2.07</td>
</tr>
<tr>
<td>use talk tbpm</td>
<td>16</td>
<td>0.64</td>
<td>0</td>
<td>1.37</td>
<td>0.42</td>
</tr>
<tr>
<td>rest tbpm/int</td>
<td>16</td>
<td>4.09/1.05</td>
<td>2.56/0.60</td>
<td>6.82/2.43</td>
<td>1.18/0.45</td>
</tr>
<tr>
<td>corrections tbpm/int</td>
<td>16</td>
<td>3/0.29</td>
<td>0/0</td>
<td>6/2</td>
<td>1.9/0.69</td>
</tr>
<tr>
<td>reviews tbpm/int</td>
<td>16</td>
<td>0.81/0.18</td>
<td>0/0</td>
<td>6/1</td>
<td>1.47/0.39</td>
</tr>
</tbody>
</table>

Table 4.1. Descriptive statistics for overall video time and time slices (in minutes) plus all corrections and review events detected in the video analysis.

is a notable difference between TBPM and interviews in the average amount of corrections (3/0.29) and reviews (0.81/0.18).

4.3.2. Data set preparation

The original experiment additionally involved process models to collect feedback from subjects. We had one more questionnaire-based hypothesis related to this feedback models and two more hypotheses assessed through video coding. The feedback models are discussed in detail in [53]. The other hypotheses are discussed in [83] but are not followed up on in this discussion. They did not hold and they do not contribute to understanding the effect of TBPM.

Apart from that, no collected data was excluded from the set. The data was tested with the Kolmogorov-Smirnov and Shapiro-Wilk test and is normally distributed. In other words, it is valid to apply the statistical instruments described in section 4.1.7. The missing TBPM video sample was not compensated except for the principal component analysis (see section 4.3.3). In that case only, we use the mean value of the TBPM variables to compensate for the missing 17th data set from the video analysis.

4.3.3. Measurement reliability and validity

According to Kirk and Miller ([70], p.19) the reliability is the extent to which ‘a measurement procedure yields the same answer however and whenever carried out’ while validity is the ‘extent to which it gives the correct answer’.

Reliability: Video coding instructions. We assess two aspects of measurement reliability. First we check the inter-rater agreement for the video coding using Cohen’s kappa coefficient ($\kappa$). It compares the two video coding results before the negotiation process. The inter-rater agreement over all videos and all coding schemes is $\kappa = .463$ where $.41 < \kappa < .60$ is a moderate agreement level [72]. Thus,
4.3. Data analysis

we interpret our video coding instructions as reasonably reliable and the results as reproducible.

**Reliability: Questionnaire items.** Furthermore, the reliability of the questionnaire is measured using Cronbach’s alpha ($\alpha$). It determines the degree to which the items related to one hypothesis coincide. In other words, whether the variables actually measure the same underlying aspect, e.g., fun. In the literature [39] $\alpha > .8$ is suggested to be a good value for questionnaires, while $\alpha > .7$ is still acceptable. All our variables had $\alpha > .8$, except for $\alpha(motivation_{Q4}) = .702$ and $\alpha(clarity_{Q8}) = .687$. We discuss those exceptions in section 4.4. Overall a high degree of reliability is indicated for the questionnaire.

**Validity: Hypothesis decomposition.** Validating whether the variables correctly describe ‘effective elicitation’ is not directly possible. We use effective elicitation as an umbrella term for the aspects of user engagement and result validation. From there we derive variables to measure these aspects.

We conduct a principal component analysis (PCA) for validation. It is a technique to determine sets of strongly correlating variables, which are approximated with one factor, the principal component [39]. Ideally, the variables would form two factors, those that reflect the measures for user engagement and those measuring result validation.

The PCA splits up the nine hypothesis variables to three factors that do not match the hypothesis decomposition. Interestingly, all questionnaire-based variables aggregate to one large principal component. These measures rely on self-perception of the subjects and therefore describe one side of the coin. The measurement instruments seem to have an overwhelming influence.

The time spent for $talking_{V1}$ and $silence_{V2}$ strongly correlate with the amount of $reviews_{V6}$ done. They form the second principal component indicating the degree to which people were involved with the task. The $corrections_{V7}$ performed build a third factor. Corrections do not seem to be strongly related to the amount of $reviews_{V6}$ performed as originally anticipated.

Overall, the principal component analysis does not support the hypothesis decomposition. Perceived measures strongly correlate indicating enormous influence of the measurement instrument. We take this as learning for future experiments that should rely either on one measurement instrument or an intelligent mix of measurement instruments. Numbers and more details on the principal components have been published in [83].

4.3.4. Hypothesis testing

We use the repeated-measures ANOVA to determine the effect of the independent variable (method) within each individual per dependent variable. In other words: to what extend did the method influence the performance of each individual? Figure 4.4 illustrates how the data is partitioned during the analysis. From the overall variability ($SS_T$), we identify the performance difference within subjects
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(SS_{W}) and can further distinguish the variation caused by the treatment (SS_{M}) and the variation not explained by the treatment (SS_{R}).

![Figure 4.4](image)

The way the data was partitioned for the repeated-measures ANOVA. The figure was adopted from [39] p.463.

The ratio of explained to unexplained variability in the dataset is described by

\[ F = \frac{SS_M}{df_M} / \frac{SS_R}{df_R} \]

where df is the degree of freedom calculated from the number of different methods (df_{M}=2-1=1) and the subject number (df_{R}=17-1=16). The critical ratio \( F_{0.05}(df_M, df_R) \) is the value to pass before the result is actually significant with an acceptance level of p<0.05. In other words, there is an error probability of less than five percent. For the variables collected in questionnaires \( F_{0.05}(1, 16) > 4.49 \) is a significant result, for the video codings we only have N=16 thus \( F_{0.05}(1, 15) > 4.54 \) is a significant ratio. In table 4.2 we sorted the variables according to descending \( F \) ratios. We also report SS_{B}, SS_{M}, SS_{R} and \( \eta^2 \) (eta squared). The value of \( \eta^2 = \frac{SS_M}{SS_W} \) describes the ratio of variation within the subjects that is explained by the treatment method. It is an effect size measure.

<table>
<thead>
<tr>
<th>dependend Variable</th>
<th>df_{R}</th>
<th>( SS_T )</th>
<th>( SS_B )</th>
<th>( SS_M )</th>
<th>( SS_R )</th>
<th>( F_{0.05} )</th>
<th>( \eta^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>corrections_{V7}</td>
<td>15</td>
<td>119.22</td>
<td>42.72</td>
<td>57.78</td>
<td>18.72</td>
<td>46.30</td>
<td>0.76</td>
</tr>
<tr>
<td>silence_{V2}</td>
<td>15</td>
<td>398.55</td>
<td>129.58</td>
<td>167.92</td>
<td>101.05</td>
<td>24.93</td>
<td>0.62</td>
</tr>
<tr>
<td>understanding_{Q9}</td>
<td>16</td>
<td>18.24</td>
<td>14.9</td>
<td>0.84</td>
<td>2.50</td>
<td>5.36</td>
<td>0.25</td>
</tr>
<tr>
<td>reviews_{V6}</td>
<td>15</td>
<td>38.01</td>
<td>23.00</td>
<td>3.13</td>
<td>11.88</td>
<td>3.95</td>
<td>0.21</td>
</tr>
<tr>
<td>talking_{V1}</td>
<td>15</td>
<td>116.56</td>
<td>56.92</td>
<td>10.86</td>
<td>48.79</td>
<td>3.34</td>
<td>0.18</td>
</tr>
<tr>
<td>fun_{Q3}</td>
<td>16</td>
<td>18.31</td>
<td>15.03</td>
<td>0.55</td>
<td>2.73</td>
<td>3.24</td>
<td>0.17</td>
</tr>
<tr>
<td>commitment_{Q5}</td>
<td>16</td>
<td>24.68</td>
<td>20.90</td>
<td>0.33</td>
<td>3.45</td>
<td>1.52</td>
<td>0.09</td>
</tr>
<tr>
<td>clarity_{Q8}</td>
<td>16</td>
<td>32.78</td>
<td>25.78</td>
<td>0.12</td>
<td>6.88</td>
<td>0.27</td>
<td>0.02</td>
</tr>
<tr>
<td>motivation_{Q4}</td>
<td>16</td>
<td>10.90</td>
<td>9.46</td>
<td>0.05</td>
<td>1.39</td>
<td>0.23</td>
<td>0.04</td>
</tr>
</tbody>
</table>

**Table 4.2.** ANOVA result table based on df_{M}=1. Sorted by \( F_{0.05} \) ratios. Values are significant for \( F_{0.05}(1, 16) > 4.49 \) respectively \( F_{0.05}(1, 15) > 4.54 \).

From the \( F \) ratios we can see that corrections_{V7}, silence_{V2} and understanding_{Q9} show significant difference due to the method. For corrections_{V7} and silence_{V2}
the variation within subjects due to method ($SS_M$) is higher than the variation between subjects which is also indicated by the high effect size ($\eta^2$).

In the extreme case, the method explains seventy-six percent ($\eta^2=0.76$) of the effect within the subjects. Interestingly, $funQ3$, $reviewsV6$ and $talkingV1$ just missed to meet the critical $F_{05}$-ratio. For all other cases the variation between subjects is bigger than the effect caused by the method. Nevertheless, $understandingQ9$ shows a significant difference and $reviewsv6$, $talkingV1$ and $funQ3$ just missed significance level. We note that for six out of nine variables, the variation between subjects ($SS_B$) is larger than the variation within subjects ($SS_M + SS_R$). In other words, the personal characteristics have a stronger impact than any treatment or other influence.

**Alternative view: t-test.** Furthermore we conduct a dependent t-test in order to create a different view on the data (see table 4.3). It compares the groups doing TBPM and interviews by their mean scores ($V =$in minutes, $Q =$Likert scale [1..5]), the statistical significance of this difference (one-tailed with acceptance level $p<.05$) and the confidence interval. The upper and lower boundaries of the confidence interval indicate that the real mean difference between the groups is probably in that range with a 95 percent chance. It should not include zero to ensure the existence and direction of the effect between the groups.

<table>
<thead>
<tr>
<th>dependent variable</th>
<th>Effect Size</th>
<th>Significance</th>
<th>Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>$correctionsV7$</td>
<td>3.00</td>
<td>0.31</td>
<td>.000</td>
</tr>
<tr>
<td>$silenceV2$</td>
<td>5.54</td>
<td>0.95</td>
<td>.000</td>
</tr>
<tr>
<td>$understandingQ9$</td>
<td>3.75</td>
<td>3.43</td>
<td>.017</td>
</tr>
<tr>
<td>$reviewsV6$</td>
<td>0.81</td>
<td>0.19</td>
<td>.033</td>
</tr>
<tr>
<td>$talkingV1$</td>
<td>4.65</td>
<td>3.49</td>
<td>.044</td>
</tr>
<tr>
<td>$funQ3$</td>
<td>4.16</td>
<td>3.90</td>
<td>.046</td>
</tr>
<tr>
<td>$commitmentQ5$</td>
<td>3.31</td>
<td>3.51</td>
<td>.118</td>
</tr>
<tr>
<td>$clarityQ8$</td>
<td>3.37</td>
<td>3.49</td>
<td>.304</td>
</tr>
<tr>
<td>$motivationQ4$</td>
<td>4.45</td>
<td>4.37</td>
<td>.225</td>
</tr>
</tbody>
</table>

Table 4.3. T-test results (one-tailed) comparing groups by method. The table is ordered like table 4.2.

As for table 4.2, we conclude from table 4.3 that all parameters for $correctionsV7$, $silenceV2$ and $understandingQ9$ are significant. The variables $reviewsv6$, $talkingV1$ and $funQ3$ have a significant $p$-value but the confidence intervals include zero and therefore do not meet the standards set. Finally, $commitmentQ5$, $clarityQ8$ and $motivationQ4$ are not significant in both tests.
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4.3.5. Testing potentially influential factors

We use a two-tailed dependent t-test to compare groups with different influences. For example, two experimenters ran the setup and subjects reported on two different processes, ‘purchasing a new flatscreen’ and ‘running the call for tenders for a new warehouse’. Furthermore, each subject goes through the experimental task twice. Repetition effects might have influenced the performance of the subjects. We use each potential factor as an independent variable and test for significant differences in the depended variables. The results are depicted in table 4.4.

<table>
<thead>
<tr>
<th>dependent variable</th>
<th>influence factors</th>
<th>reported process</th>
<th>1st vs. 2nd run</th>
<th>experimenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>corrections&lt;sub&gt;V7&lt;/sub&gt;</td>
<td></td>
<td>.700</td>
<td>.939</td>
<td>.119</td>
</tr>
<tr>
<td>silence&lt;sub&gt;V2&lt;/sub&gt;</td>
<td></td>
<td>.738</td>
<td>.996</td>
<td>.448</td>
</tr>
<tr>
<td>understanding&lt;sub&gt;Q9&lt;/sub&gt;</td>
<td></td>
<td>.439</td>
<td>.439</td>
<td>.984</td>
</tr>
<tr>
<td>reviews&lt;sub&gt;V6&lt;/sub&gt;</td>
<td></td>
<td>.493</td>
<td>.483</td>
<td>.160</td>
</tr>
<tr>
<td>talking&lt;sub&gt;V1&lt;/sub&gt;</td>
<td></td>
<td>.963</td>
<td>.854</td>
<td>.221</td>
</tr>
<tr>
<td>fun&lt;sub&gt;Q3&lt;/sub&gt;</td>
<td></td>
<td>.532</td>
<td>.091</td>
<td>.618</td>
</tr>
<tr>
<td>commitment&lt;sub&gt;Q5&lt;/sub&gt;</td>
<td></td>
<td>.484</td>
<td>.004</td>
<td>.516</td>
</tr>
<tr>
<td>clarity&lt;sub&gt;Q8&lt;/sub&gt;</td>
<td></td>
<td>.116</td>
<td>.001</td>
<td>.750</td>
</tr>
<tr>
<td>motivation&lt;sub&gt;Q4&lt;/sub&gt;</td>
<td></td>
<td>.013</td>
<td>.450</td>
<td>.066</td>
</tr>
</tbody>
</table>

Table 4.4. Potentially influential factors tested for their significance with a two-tailed t-test. motivation<sub>Q4</sub> was significantly influenced by the reported process. commitment<sub>Q5</sub> and clarity<sub>Q8</sub> were significantly influenced by repetition. The table is ordered like table 4.2.

While the experimenters had no significant influence on the dependent variables, we found that the second experimental task led to significantly more clarity<sub>Q8</sub> (1st=3.1, 2nd=3.77, p=.001, lb=-0.99, ub=-0.34) about the goal of the session and more commitment<sub>Q5</sub> (1st=3.2, 2nd=3.63, p=.004, lb=0.70, ub=0.16) to the solution created. Finally, people reported to have a significantly higher motivation<sub>Q4</sub> (warehouse=4.53, flatscreen=4.29, p=.013, lb=0.05, ub=0.42) for sessions in which they talked about the process of ‘running a call for tenders for a new warehouse’. We discuss the implications of these findings when we interpret the results in section 4.4.

4.4. Interpretation of results

We identify three types of variables. Those that (1) significantly support their hypothesis, those with a (2) strong tendency towards support of their hypothesis, and those that (3) do not indicate support for for their hypothesis. We discuss them in groups according to the support level.

Supportive variables. The video analysis indicated that people spent much more time in silence<sub>V2</sub> in TBPM modeling sessions than they spent in interviews
We argue that this is additional time to think about the model and validate it. This is also reflected in significantly more corrections observed for TBPM sessions ($F_{0.5}(1,15)=46.30, \eta^2=0.76$), which are supported by more time for thinking. When questioning the subjects, they responded that they have built significantly more understanding for the process ($F_{0.5}(1,16)=5.36, \eta^2=0.25$).

We indicated in section 4.1.1 that process understanding is a competency gained by applying TBPM modeling. It was measured as a perceived value. It might have been supported by the additional time to think because as subjects think about their process and incorporate corrections, they build more confidence about the process and therefore have a significantly better perceived process understanding.

In all three cases (corrections, silences and understanding), we found significant support for our hypotheses without unintended influences or flaws in the measurement instrument.

**Tendency variables.** The time spent on the problem was decomposed into time spent silent (discussed above) and time spent talking. While the time spent silent showed significant difference between the groups, the time spent talking missed the critical F-ratio ($F_{0.5}(1,15)>4.54$) for statistical significance ($F_{0.5}(1,15)=3.34, \eta^2=0.18$). However, that is a marginal gap and a strong tendency towards hypothesis support. This claim is also based on the t-test results in table 4.3. While talking meets the significance level ($p=0.044$) with dramatic effect sizes (TBPM=4.65min, int=3.49min), the confidence intervals are not acceptable (lb=-0.19min, ub=2.52min). Here we miss scientific standards by twelve seconds. When recombining talking and silences, the time spent on the task would actually be significant and acceptable.

Similarly, the amount of reviews conducted just missed scientific standards in the repeated-measures ANOVA ($F_{0.5}(1,15)=3.95, \eta^2=0.21$). Again, the t-test indicated a significant ($p=0.033$) difference with notable effect sizes (TBPM=0.81, int=0.19) but unacceptable confidence intervals (lb=-0.46, ub=1.30). It is still a strong tendency towards hypothesis support and we also bear in mind that silent reviews are measured as time thinking (silence, $F_{0.5}(1,15)=24.93$) due to the strict coding guidelines. Furthermore, reviews are a pre-requisite for corrections ($F_{0.5}(1,15)=46.3$) which also was significantly higher for TBPM sessions. In other words, some reviews might have been counted as silent and the significantly more corrections indicate that there must have been reviews associated.

As for reviews and talking, we see fun on the way to support its hypothesis ($F_{0.5}(1,16)=3.24, \eta^2=0.17$). Like the other two variables, fun missed the critical F-ratio ($F_{0.5}(1,16)>4.49$) and has proper significance in the t-test ($p=0.046$) but without acceptable confidence intervals (lb=-0.05, ub=0.56).

For all these variables (reviews, talking, fun), we see a strong tendency towards a significant result. Strictly speaking, we failed to show the effect exists with scientific rigor in this experiment. Mathematically speaking, a slightly larger sample set might have made the difference. We see great potential for these variables to support their hypotheses an experiment with more participants.
Unsupportive variables. We neither found support nor tendency for the variables commitment\textsubscript{Q5}, clarity\textsubscript{Q8} and motivation\textsubscript{Q4}. It does not mean the opposite for the related hypotheses. We could simply not observe the expected effects. Yet, additional analysis yields additional insights:

In section 4.3.5, we learned that clarity\textsubscript{Q8} is significantly higher for the second experimental task (1st=3.1, 2nd=3.77, p=.001). We conclude that a task is clearer if undergone for the second time. In this case also, people report more commitment\textsubscript{Q5} (1st=3.2, 2nd=3.63, p=.004) to the solution. We interpret this as a learning effect. As people repeat a task they have a clearer understanding of the session goal and are more committed to what they did as they gain confidence. This also implies people will need some practice when applying TBPM as confidence builds up with repetition.

Subjects also indicated higher motivation\textsubscript{Q4} (p=.013) when they reported on the process of ‘running a call for tender for a new warehouse’ (warehouse=4.53, flatscreen=4.29). It might have been either a more challenging task or a more realistic process to report on. We also note that the motivation in general was very high (TBM=4.45, int=4.37). Subjects volunteered to take part. They got off from class, a cinema voucher, and a chocolate bar as rewards. An average of 4.41 on a five-point Likert [1..5] scale is a very high value. In those cases it is much harder to detect a statistically significant difference between groups.

All three variables (commitment\textsubscript{Q5}, clarity\textsubscript{Q8} and motivation\textsubscript{Q4}) were not supportive. We can draw insights from further analysis, such as the effect of repetition. We have to bear in mind that motivation\textsubscript{Q4} and clarity\textsubscript{Q8} both lacked internal consistency as assessed in section 4.3.3. Their expressiveness is therefore limited.

Hypothesis tree discussion. We reject $H_{02}$ due to the findings from section 4.3.4 and see a tendency towards rejectability of $H_{01}$ and $H_{03}$. Thus, there is a wide support for the aspect of engagement through activation (see figure 4.5). We can not conclude on the concept of identification for engagement. The hypotheses were not well operationalized and the measures have been confounded. Thus we do not reject $H_{04}$, $H_{05}$.

Validated results are supported by more feedback which is indicated in significantly more corrections\textsubscript{V7} and a strong tendency towards significantly more reviews\textsubscript{V6}. We reject $H_{07}$ and see a tendency towards the rejectability of $H_{06}$.

Like commitment\textsubscript{Q5}, the clarity\textsubscript{Q8} rises with repetition of the experimental task. We take this as learning for TBPM but do not reject $H_{08}$. Finally, we reject $H_{09}$ because people reported a significantly better understanding\textsubscript{Q9} for the process when using TBPM as a modeling tool.

We illustrate the evaluation of the hypotheses in figure 4.5. While the hypothesis decomposition enabled insights into the way TBPM influences the outcome of process elicitation sessions, its validation failed. As discussed in section 4.3.3, the measurement instruments had a steering effect. When people report perceived measures, they tend to interrelate. For example, subjects may report high values for commitment\textsubscript{Q5}, understanding\textsubscript{Q9}, and clarity\textsubscript{Q8} on the Likert-Scale. Others might not be in a good mood and report low values for these measures. In
4.4. Interpretation of results

**Figure 4.5.** Evaluated Hypothesis tree illustrates the hypothesis decomposition from figure 4.1 in the light of the findings from the experiment.

statistical analysis, these measures interrelate strongly in comparison to measures taken from the video analysis. While this is an interesting learning in itself it interferes with the validation of the hypothesis decomposition.

### 4.4.1. Validity threats

We discuss internal and external validity threats according to [16, 150].

The internal validity addresses the relationship between cause and effect. In particular, we discuss the influence factors. The external validity addresses threats to the generalizability of findings.

**Internal validity.** The internal validity was addressed by the experiment design and assessed in section 4.3.5. In particular, we use two processes and two experimenters assigned in randomized order. The experimenters did not harm the internal validity. One process (warehouse) made subjects report more motivation\textsubscript{Q4} but the same variable does not support its original hypothesis. Thus, it did not lead to a biased conclusion. Similarly, we found a learning effect due to the repeated measurements design on the aspects of clarity\textsubscript{Q8} and commitment\textsubscript{Q5} which do not change significantly due to the experimental treatment. Thus, we do not see a threat to our conclusions.

**External validity.** One might argue that we choose non-representative subjects and topics for our experiment. We selected a sample group that is representative for the people we want to address with TBPM, domain experts. The demographics of the population was limited to subjects at the age of 19 to 21. Yet, we do not see specifics in the age of our subjects that could harm the generalizability of findings.
4. Controlled experiment with individuals

We chose processes from the domain of the students in coordination with the school to ensure all subjects are equally familiar with them. However, we missed to assess to which extend individual subjects were familiar with these scenarios in their companies.

4.4.2. Generalizability of findings

We think the findings about TBPM can be generalized from the sample group to the general population of clerks. Besides their age (19-21years) the students represent exactly the group of domain experts that we want to address with the TBPM tool. Clerks are domain experts that might get questioned by BPM experts in business process modeling projects.

Furthermore, our findings might hold for other tangible modeling techniques when compared to pure talking. The findings should be independent of a process modeling notation (e.g. EPCs [67]) or even any other modeling technique such as Entity-Relationship modeling [20]. As an example, instant and frequent feedback was also reported [122] for user interface designs conducted together with users. Yet, we are conservative suggesting that the findings will at least hold for tangible process modeling in any notation.

We measured the effect within individuals in a one-to-one situation. We think that the positive effects, such as increased fun and model iterations, will basically hold also for people working in groups. Yet, group interactions add a layer of complexity on top. Therefore it becomes harder to determine whether an effect was caused by the tool or by the actions of other subjects at the table.

4.4.3. Lessons learned about the experiment setup

If we had to start over again and redo this experiment, we would cut it down to the six hypotheses that have the strongest contribution to explaining the effect of TBPM. From the questionnaire, we learned that the variables measured with one instrument strongly correlate. We suggest to split each variable to be measured with different measurement instruments. Ideally, we complement perceived measures with external measures such as video codings. We also had to learn that rigor video analysis is the most time-consuming evaluation task. One hour of video took about five person-days for analysis and negotiation.

Besides all that, we think that the compact on-site experiment proofed to be practical. Instead of spreading out the experiment over various weeks with changing conditions, we could collect the data in a compact week with a stable setup. Moreover, the two experimenters reviewing each others work ensured a stable setup.
4.5. Summary of findings from the experiment with individuals

We conducted a controlled experiment to compare TBPM with structured interviews. We seek to determine effects caused within subjects when applying TBPM for process modeling. All subjects were exposed to two treatments in random order, interviews and TBPM modeling. The effects were determined by observing subjects during the treatment and collecting a questionnaire after the treatment. We collected the data according to the hypotheses and performed statistical analysis. We learned the following effects:

- **TBPM modeling activates people**: People report to have more fun with TBPM than with interviews. It goes together with a stronger activation to engage with the task of process elicitation. In particular, people take more time to talk about their process and spend more time silent. The time spent silent is presumably used to think about the process. This additional user engagement creates time needed to build a deeper understanding for the process and provide more feedback.

- **TBPM modeling fosters feedback**: People using TBPM validate the process model. In particular, they review it more often and apply more corrections to the process story than people being interviewed. Supported by more user engagement, the additional reviews and corrections lead to more validated process models as the result of the process elicitation session.

- **TBPM modeling builds understanding for the process**: People reported more understanding for the process itself after applying TBPM instead of talking about the process in an interview. Together with more time taken and more feedback given this leads to more validated process models as the result of TBPM elicitation sessions.

Additional observations: the power of repetition. The data collected was evaluated from various viewpoints. When assessing repetition effects we learned that people report more clarity about the session goal and more commitment to the solution that they contributed for the second experimental task. This effect is independent of the method applied and underlines the importance of learning by doing. As people do, they feel more confident about their doing and the results.

Additional observations: the people matter. The performance variation between subjects is typically higher than the performance variation caused by the treatment. In our case, six of nine variables varied more between than within people. In other words, if there is a choice between the best technique or the best people, we suggest to favor people over elicitation technique. Yet, given the same people, we have shown that the TBPM modeling technique can make a difference (see above). For three of nine variables the effect caused by the tooling even supersedes the individual preferences.
4. Controlled experiment with individuals

**Limitations of the controlled experiment.** We worked with young clerks in a trade school as proxies for clerks to be encountered in real projects. We checked for validity threats that might limit the portability of our findings (see section 4.4.1). Yet, the controlled laboratory experiment itself is a fundamental limitation. By definition, it is an artificial environment in which only predefined variables are observed and can contribute to the knowledge creation. Other aspects might have been overlooked.

Finally, only individuals have been observed and only the effect within them was investigated. Yet, we envision elicitation with TBPM to be most valuable with groups of domain experts because they can co-create the process model together. In those cases, a methodological guidance by an experienced modeling facilitator is needed.

**More research needed.** The controlled experiment contributed to the research goal to compare our solution and existing approaches for process elicitation. It brought us nearer to understanding the effects of the TBPM toolkit itself. Yet, it did not create the knowledge required for a successful application in practice. To complement our research in the laboratory with individuals, we propose to conduct field research with groups. We dedicate chapter 5 to the investigation of TBPM in real project settings.
5. Field research with groups

We have investigated the effectiveness of TBPM in a laboratory environment with individuals in the previous chapter. This chapter investigates the efficiency of TBPM in the real world with groups of people. Parts of the findings from the field research were also published in [85].

Our goal is to ensure the TBPM technique is applicable in practice. The first workshop application in the field, described in section 3.5, indicated that the application is feasible. Practical guidance is needed that explains when and how to apply TBPM modeling. We consider the goal to be reached if we can show that – given the appropriate setting and guidance – TBPM workshops are an alternative in productivity and result to other modeling techniques. The key artifact to be created in this research phase is guidance for practitioners with respect to when and how to apply TBPM.

When to apply TBPM? No single technique is always suited for all scenarios. A technique needs to fit into the context in which it shall be used. Therefore, we need to define that context as the people, the setting, and the processes that welcome TBPM as a process elicitation technique. This shall help business process modeling (BPM) experts to identify candidates for TBPM application.

How to guide the BPM expert? We learned in previous applications that a BPM expert should guide the group in the role of a game master through the journey of process model creation. We envision an experienced BPM expert applying TBPM for the first time. He knows process elicitation techniques but expects advice on how to structure and facilitate a TBPM workshop. We want to avoid common pitfalls and related frustration, which might hamper the TBPM workshop potential from being realized.

Research Setup. We opt to conduct our research in the field to make TBPM work in realistic project settings. Field research – in contrast to laboratory research – is undertaken in a given business context with actual users rather than proxies as subjects. We collaborate with BPM experts on their job. As they try out TBPM, we observe them, learn from them, and propose alignments according to scientific theory. This enables us to stay open for new insights from experienced BPM
5. Field research with groups

experts. This research setup also calls for iterations, as we do not know upfront what we will find.

We choose action research as the scientific method to guide us in the collaboration with practitioners. We explain this method in section 5.1 and subsequently apply it in two cases. The derived method guidance is presented in section 5.4. The findings are discussed in section 5.5 and the field research is summarized in section 5.6.

5.1. Action research method

Action research (AR) is a class of research methods in which researchers collaborate with practitioners to act in or on a social system [13]. The goal is to solve practical problems and generate scientific knowledge. Action research assumes that complex social problems cannot be reduced to a meaningful controllable study. They need to be investigated within the context in which they appear. Therefore, the system is studied, changed, and the effect of change is studied again. This is an iterative process. Kurt Lewin described it as a spiral of ‘planning, action, and fact-finding about the results of the action’ [75].

Principles for action research. Some criteria have been proposed to ensure quality standards in action research [29]. These principles – for so called canonical action research – are suggestions for an ideal world. We take them as guiding input to raise the validity of our studies by avoiding pitfalls:

- **Researcher-client agreement:** The partners need to agree on the timeframe and the nature of the collaboration. Thus, the ‘client’ is aware of implications of the research method and is committed to collaborate throughout the full length of the study.

- **Cyclic phase model:** The research should follow a cyclic research model (see figure 5.1). Each phase of the model should be conducted with rigor. Knowledge from one phase needs to be carried over to the next phase. Furthermore, knowledge from one case should be carried over to the next iteration.

- **Theory:** Researchers should base their interventions on theoretical frameworks. Some researchers argue: ‘without theory there is no research’ [87] while others reply that it is impossible to know the theory to be used already in advance [25].

- **Change through action:** The situation should be changed to improve it. A meaningful problem must be chosen and specified. A hypothesis about the effect of the change should be formed. The action should implement the change.

- **Learning through reflection:** After the action, the researchers and clients should reflect on the outcome. Thus, data may be collected during or after the action for evaluation. Learning happens when the implications of the observed effects become apparent.
Action research model. We adopt a five-stage model proposed by e.g. Baskerville [7] as described in figure 5.1. The way this cycle is operationalized in studies varies [132]. In particular, the degree of collaboration between practitioners and scientists for each of the phases is different depending on setting and preferences. Some phases may be driven by the researcher alone, others by the practitioners. We describe the operationalization of the phases in the following paragraph.

![Action research cycle](image)

**Figure 5.1.** Action research cycle adopted from [7] and used in this chapter to guide the research collaboration with practitioners in section 5.2 and section 5.3.

Research model explained. After introducing the context for each study, we start with diagnosing the problems in the given context. These problems become challenges to be tackled in the current action research case. In action planning we describe the desired future state and propose changes. Proposed changes may be based on existing scientific findings or – if not applicable – are created in collaboration with the practitioners. These changes are to be assessed for their expected effect. The first two research phases – diagnosing and action planning are carried out in close collaboration with the practitioners. In taking action the practitioners act alone while the researchers observe and concentrate on data collection for the evaluating phase. In the evaluation, we assess whether the proposed changes realized the anticipated effect and whether the practitioners’ problems were solved.

Finally, we step back from the specific case in specify learning to derive more general conclusions, practically and scientifically. This last phase determines knowledge and questions to carry over to other cases in subsequent iterations of the action research cycle. Each study performed in this chapter, represents one iteration of the action research cycle.

5.2. Study1: Iterating the group modeling setup

In mid 2009, a BPM consultant used the TBPM toolkit to capture clinical pathways in a hospital with doctors. A clinical pathway is a treatment process for a class of patients with a similar disease, e.g. a certain type of cancer. We described this case in section 3.5.
5. Field research with groups

This was the first application of tangible business process modeling in the workshops with groups. Within one week, the group modeled twenty BPMN processes. The workshop was considered a success by the BPM consultant. In mid 2010, the same consultant approached us again with the same request. The setting was very similar, only the participants and the clinical pathways were changed. This was the starting point for the first action research cycle.

Diagnosing. When reviewing the workshop from 2009 together with the BPM consultant, we agreed that the introduction to process modeling was not optimal. Originally, a one-day introduction to BPM and BPMN was given as a front lecture. Modeling only started on the second day. We agreed that a shorter lecturing phase would be possible with a more suitable introduction.

Another problem was the confusion about media in the 2009 workshop. Tangible tiles, paper printouts, and software were all present during the workshop. Jumping between media created different embodiments of the same process model with different versions. A clear guideline was needed that matches the media with the purpose of the modeling phase. Such a guideline would need to be created.

Finally, as researchers, we wanted to investigate to which extend data collection is feasible in such a research environment and what can be traced from the data. At that point, we were not sure which data to trace in order to characterize modeling sessions and their results.

Action planning. The consultant worked out a half-day BPMN introduction. As researchers, we proposed warm-up modeling exercises to enable a quicker start with process modeling. The exercises capture process models of everyday situations so that everybody is equally aware of the content and can contribute (see exercises in figure 5.2, left). This was based on the idea of learning by doing [3]. We got inspired to do this because we found in the experiment evaluation (see section 4.5) that people gain more clarity and confidence through repetition. In other words, skill comes with practice. We collected modeling exercises from practitioners and scientific literature such as ‘withdrawing money from an ATM’, inspired by Rittgen [115]. These scenarios enable participants to get familiar with process modeling without getting lost in domain specific discussions. We furthermore define a media framework (see figure 5.2, right) that proposes to (1) use tangible tiles on a table to generate models, (2) use printouts for reviews, (3) use software to archive models and (4) complement conversations with drawings. This was inspired by the research of Edelman [35] on the role of media in steering conversations (see also section 2.5). For data collection, we sent an observer to take photos and detailed notes during the workshop.

Action taking. Again, a one-week workshop was conducted. Three participants from the hospital worked out the clinical pathways for liver transplantation together with the consultant. The introduction to BPM and BPMN was shortened to half a day. The second half of the first day was used to model a pizza-ordering process as warm-up exercises and discuss modeling decisions. In the following four days, the doctors modeled thirteen processes together with the consultant. Figure 5.3 shows
5.2. Study 1: Iterating the group modeling setup

Warm-up exercises:
- pizza ordering process
- withdraw money from an ATM
- getting up in the morning

Media framework:
- generate models using TBPM
- review models on print-outs
- use software to archive models
- use drawing in conversations

Figure 5.2. Guidance prepared for the workshop: scenarios for warm-up exercises (left) and a media framework (right).

Some impressions from the workshop. In total, we collected more than six hundred pictures, nine pages with observer notes, and interviews with the consultant and each participant. From the modeling sessions, we collected six snapshots of the project during the week documenting the process models at their current state.

Figure 5.3. Clinical pathways modeled with BPMN semantics in a one-week TBPM workshop. Modeling with TBPM (left) and reviewing digitalized models on print-outs (right).

Evaluating. In interviews at the end of the week, the participants qualified tangible modeling as well suited to adopt the idea of process modeling. The warm-up exercise in the beginning was perceived as an adequate part of the introduction. The consultant liked the way in which the modeling exercise complemented the introduction and activated participants early. In his opinion the contribution to learning BPMN is not very high, but the modeling exercise reduces the barrier to start working with the tool and the notation. All together, the introduction and modeling exercise consumed the first day of the workshop.

The consultant classified the media framework as a good idea to keep in mind. However, it should not be regarded as a golden rule and may not necessarily be practical in all situations. To mention one exception, on day the participants added role information to all existing models. They did this by coloring process
steps in printed models (see figure 5.4, left). Strictly following the proposed media framework would have implied recreating tangible models to add this information. In other words, the print-outs were not only used for reviews, as proposed, but also to add process information. This exception illustrates how situational factors may overwrite guidance rules. In interviews, participants said to have experienced the media choices as natural.

The observer notes and photos were analyzed to identify patterns. From the notes, we could trace four different working modes during the workshop week: Participants got introduced to new modeling knowledge, participants modeled, the consultant archived the process models in the evenings using the software tool, and everybody reviewed results. These modes happened in a cyclic pattern: (1) introduce, (2) model, (3) archive, and (4) review. We visualize this pattern in figure 5.4 (right). The diameter of each bubble represents the amount of time spent in this mode during the week. The arrows indicate status changes from one mode to another. The thickness of arrows indicates the frequency of changes.

Additionally, we used the models in their various evolution stages throughout the week to explore their properties. We characterized them using process model metrics by Mendling [91] and identified candidate metrics that would indicate modeling progress and modeling productivity. By comparison, we found that the amount of information in a BPMN model can be well approximated by counting the amount of edges and nodes in the model (see figure 5.5, left). Every information – except for role information – is represented as a node in BPMN. Each node is connected to the rest of the model by at least one edge. By summing up all nodes or edges in all models, we can approximate the size of the overall modeling project. We favor to count and sum edges instead of nodes here. Edges also increase when a document gets connected to multiple activities at a time. Other modeling languages require the introduction of replicated nodes for this case, but BPMN allows one node connected with a multitude of edges. By counting nodes, this additional information would not be represented by the measure. Therefore we chose to count edges.
5.2. Study1: Iterating the group modeling setup

Dividing the amount of edges by the time spent on the task, enables us to approximate the modeling productivity per hour. This seemed to be a useful indicator for productivity because it describes the information that was added per time unit (see figure 5.5, right). We see that there is a maximum productivity, which seems to stabilize around 33 edges/hour after some iterations. It indicates the maximum modeling productivity of the group using TBPM. Numbers do not tell all the truth about a real world situation but the measures chosen here are an abstraction that seems suited to compare modeling productivity and progress in different workshops. Unfortunately, in this special case – modeling with hospital staff – there is no data to compare with.

Figure 5.5. Process model metrics [91] applied to the progressing modeling project (left) and delta of information added per modeling session divided by the time spent modeling as edges/hour and nodes/hour (right). The explorative evaluation indicates that it is possible to approximate workshop progress (left) and workshop productivity (right).

Finally, we asked the consultant for his preferred alternative to tangible modeling and he responded: ‘There is no alternative. I knew it would work from our previous workshop. If I did not have this option then I would have had to do interviews. If you are not an expert in the domain – and I am not an expert – good luck understanding your client.’

Specify learning. From this field study, we learned that participants and the consultant perceived the warm-up modeling exercise as useful. It did shorten the time to start modeling, but overall it did not save time in comparison to the previous workshop. Yet, they started modeling earlier and familiarized with the tool already. The actual modeling of content started in both cases at the second day.

We also learned that the media framework is a good idea to guide consultants in the selection of media for the workshop. However, it is not a golden rule. Media must be chosen specific to the situation. For example, the role information was added on print-outs because that did fit the particular situation in the workshop.

We learned that observation notes and photos are rich information that can be used to trace e.g. the work phases. From the transition of work phases, we identified a natural modeling cycle (see figure 5.4, right).
5. Field research with groups

When combining observations with intermediate process modeling results, it is possible to trace workshop productivity, as information mapped per hour. The productivity and process data itself, however, is less meaningful without proper data to compare with. Ideally, the data would come from the same facilitator using different tools. We conclude that we discovered suitable measures but data for comparison is missing.

By reviewing the workshops from 2009 and 2010, we identified themes that worked well. From that we derived the first practical guidance for moderators and iterated it with the consultant. The guidance was about topics such as the modeling phases, the media framework, warm-up exercises but also setting and modeling guidelines (see section 5.4 for details). This guidance is a learning to be carried over to further workshops in other contexts. To complement our existing findings, we need to find data to compare with. We identify the following research question to be most pressing for a subsequent action research study:

*How productive is tangible modeling compared to other workshop techniques?*

5.3. Study2: Comparing workshop techniques

In early 2011, an in-house BPM consultant working for a subsidiary of a large energy provider in Germany contacted us. The company is responsible to develop and test new ideas for the energy market such as smart-home devices and e-mobility concepts. Within this company, the BPM department captures and improves organizational processes in workshops together with domain experts. A modeling workshop lasts three hours and is run by two people, a moderator and a software tool expert. While the moderator elicits information in a conversation with the participants, the tool expert translates the information into a process model on the fly. The computer screen is simultaneously projected to a wall. The participants can see the process model evolving and review it. This is an example of a software-supported workshop as described in section 1.3.2. In this case, the process modeling notation is EPC [67] and the software tool is ARIS [121]. The in-house consultant approached us because he saw a need for a different elicitation technique in specific workshop situations.

**Diagnosing.** The process modeling team worked on more than six hundred process models together over the past years in this setting. Most of them related to processes with high volume instances, such as customer billing with hundreds of thousands of clients. If the process is well established, e.g. because it is well supported by a software system, the participants talk to the consultants about it and the tool expert creates the model immediately. However, if the process
is not well established – because it is a low volume process with only a view occurrences per year – or it is to be designed, then participants need to discuss the information and reach consensus before it goes into the model. They need a way to easily go through alternative scenarios. Here, the BPM experts observed problems because participants miss possibilities to express their thoughts and try out ideas for themselves. If there is a conflict between the modeled information and the real information, it is barely expressed during the workshops because the participants are not in charge of the tool, the BPM experts said. These conflicts pop up in subsequent workshops when the previous workshop result is reviewed on print-outs.

The BPM experts explained, that the problem is amplified by the limited overview of the process model during the workshop. The intermediate model is projected to the wall. A typical screen resolution for projectors is 1024 by 768 pixels but even a full HD resolution (1920 by 1080) would not enable to see large models all at once. This causes participants to lose the overview and drop out of discussions. Dropping back in is almost impossible as the discussion progresses and a different snippet of the model gets displayed on the screen.

The team of BPM experts that we work with has conducted several workshops in such an environment. Results are accessible from the organizational handbook and for some cases the effort of modeling workshops can be traced. This is an ideal setting to compare TBPM productivity and results with other workshops. However, the tangible modeling tool needs to be adopted to work with the EPC notation first.

**Action planning.** We designed a tangible EPC modeling toolkit and tested it in a prototyped workshop at the university. We wanted to mimic the existing workshop situation at the energy provider but change the modeling tool. Instead of the software tool ARIS and a dedicated tool expert, we proposed to use a tangible version of EPCs (see figure 5.6, left). The moderator insisted on the software and the tool expert as a backup. Thus, the model was created on the table by the group and digitalized for documentation by a dedicated software tool expert in parallel.

We specified together with the modeling team a suitable context for tangible modeling workshops. The participants should not be afraid of an open discussion and have a positive attitude towards active workshop participation. Furthermore, we needed low volume processes that are either not yet regulated or about to be standardized. Defining models for these processes requires a lot of discussion among the stakeholders. The participants can benefit from a tool that enables co-design of process models. Finally, we wanted to tackle a new area in which the BPM experts had no expertise either. In such a context, TBPM would play out its benefits over software-supported workshops. To share our insights about TBPM modeling, we briefed the BPM experts about the existing method knowledge.

Within the company the department for idea management was identified as suitable. The department was formed one year earlier and just grew from two to three employees. The processes were not modeled yet but they looked for software to store, rate, and track their ideas. Two workshop sessions were scheduled at
two subsequent days. The workshop objective was to create an overview of the existing processes in this department and to model the core process that would benefit from software support.

Figure 5.6. Left: The tangible modeling toolkit adopted to be used with EPC notation. Right: Software-supported workshop situation post-positioned: Tool expert, moderator and the digital model projected to the wall.

To collect data, we sent two observers to the workshop. Furthermore, we got access to 22 processes of a similarly structured department taken from the organizational handbook. It serves as a reference point for typical processes of a small department captured by this team of BPM experts in the same company. To trace productivity, we collected effort estimations – as workshop time per model – for a recently finished modeling project from yet another department. This project spanned 18 models describing high volume business. It serves as a reference point for high productivity workshops conducted by this team with their existing technique.

Action taking. The first workshop – although scheduled for 3 hours – started late and ended early due to other business commitments of the participants. Two out of three hours actually remained. Within that time, the moderator gave a standard ten-minute introduction about the need for process modeling and the company view on the topic.

At first, the processes for this department were collected and mapped on Post-Its in a brainstorming. Subsequently, the workshop participants consolidated the process landscape by re-arranging the Post-Its. At this stage, it turned out that the scope of this department was not entirely clear. Creating this map consumed the first workshop hour. In the remaining time, the tangible EPC set was introduced for about three minutes and the first steps for the ‘idea creation and evaluation’ process were mapped.

The next day started with a review of the existing process snippet. The main path was completed and two alternative paths were modeled. Iteratively, each path was enriched with further details such as roles, documents, and IT systems. As proposed, the information was attached to the function shapes using colored Post-Its, each color representing either roles, documents, or IT systems. This
5.3. Study2: Comparing workshop techniques

Figure 5.7. The tangible modeling workshop conducted at a large energy provider. Starting to model with TBPM (left). Reviewing and discussing the mapped process together (right).

created a compact process model, in comparison to digital EPCs which have nodes and edges for each information attached to functions. Three reviews were done during the workshop, one after each completed path. Many more small reviews were conducted in the form of individuals scanning parts of the model. When people dropped out of the active discussion, they typically starred at another part of the process. At least two of these situations led to new discussion points or corrections. Similarly, people talking about the process jumped with their eyes and fingers from one end of the process model to the other. This was done to identify inconsistencies, cross-reference parts of the process, or literally point out an argument in the discussion. We collected three pages of observer notes and 112 photos including four snapshots of intermediate modeling results. We conducted interviews with the moderator, the software tool expert and one of the participants after the workshops.

Evaluating. The interviewees expressed satisfaction with the workshop result. The software tool expert attributed the strong activation of participants to the non-technical, puzzle-like nature of tangible modeling. The moderator said he expected the participants to model themselves, therefore it was not surprising to him that they drove the modeling session. For him, standing, pointing, and talking already creates an active atmosphere and thereby adds value to the workshop. This is in-line with our observations from study 2 in section 3.4. The moderator also mentioned, that the affordance to move tiles and try out alternatives replaces review discussions at later stages.

We interviewed one participant and he reported that he likes playing an active role in workshops in general. Thus, being an active workshop participant was not a new experience. He sees benefit in creating the process together at the table. When asked about the next step – reviewing the digitalized EPC model – he said: ‘I won’t look at it. There is nothing to gain. I was here. I know what is in the model’. Limited review interest might apply to all types of workshops, which makes active participation and corrections during workshops even more valuable.
5. Field research with groups

![Diagram of information items modeled across phases](image)

**Figure 5.8.** The result of each modeling phase quantified as nodes and characterized by the type of information. Phases are different in duration and productivity leading to different progress for each phase.

The digital EPC printed on A3 paper was hardly comprehensible because the model was shrunk beyond readable label sizes. A projector would only have shown a small percentage of the overall model at a time. The same model in a tangible representation was overlooked on a three by one meter table. Both observers independently noticed participants jumping from one end of the model to the other in order to point out something or correct information.

We evaluated the workshop productivity by quantifying the information added to the model in each tangible modeling session (see figure 5.8). This time, each node in the graph was considered countable information because EPCs use nodes for each information every time it is used. For example, if one role is responsible for three activities in the process, the corresponding role node gets reproduced three times in the process representation. In four modeling phases 19 to 47 information nodes were mapped within 30 to 72 minutes. The average amount of information nodes added per hour varied from 25 to 39.

We compared the tangible workshop productivity – 25-39 nodes mapped per hour – to 18 processes from a recently finished modeling project with 6-67 nodes/hour. In Fig. 5.9 (left) the modeling productivity is related to the size of the model. The ‘tangible modeling’ data points represent the modeling productivity in the four modeling phases related to the size of the growing model. We see that TBPM modeling productivity is quite stable no matter the model size. In other words, the productivity does not change with larger models, in particular it does not get slower. We conclude that tangible modeling is competitive to the software-supported technique for small model sizes. While software-supported modeling workshops are slower than TBPM for models with less than forty nodes, their productivity raises dramatically when the model grows.

We investigated for a reason of this unexpected effect. We found copy-and-paste to be the dominant accelerator for digital modeling tools. The bigger the models, the more substructures get re-used. As an example, in accounting the invoicing...
is handled differently according to the contract type. After the process for one contract type is modeled, it gets copied and adapted for the other case. In the end, the different paths involve different IT systems but do not differ much in the steps taken or the roles responsible for the steps. By copying and pasting model parts, a digital modeling tool can speed up the creation of model parts dramatically with up to 67 nodes modeled in one hour in the sample project evaluated. This relation was an unexpected finding. We see model size and reusability of other model parts as a candidate to determine the tool choice for modeling workshops.

Figure 5.9. Left: workshop productivity related to model size for 18 models derived in software-supported workshops and the four modeling phases observed in the tangible modeling workshops. Tangible modeling is quite stable in productivity, while software-supported workshops get more productive with bigger models. Right: boxplot diagram characterizing 22 models of a similarly structured department. The additional data points characterize the tangible EPC model. Data indicates that tangible modeling creates typical process models just like other modeling techniques.

To compare results, we characterize the models according to the size and types of information captured in the model. For this evaluation we counted the amount of node type occurrences in the models. In figure 5.9 (right) we compare the tangible modeling result to 22 processes modeled by the same BPM experts in a similar department. We use a box-plot to show the distribution in the sample set. The data points represent the attributes of the tangible model. We see, that the values from tangible modeling are in range except for role information. When following up on this, we found that the idea management department heavily collaborates with other departments, the management, and external partners, such as universities. Thus there is a high amount of role information in the model that was created.

We take all this data with caution. The diagrams in figure 5.9 compare one tangible model with a small set of case data. This comparison does not have the statistical expressiveness like e.g. the data analysis we did in chapter 4. In other words, they contain no statement about the general population.

Specify learning. For the practitioners the modeling workshop was almost business as usual. As researchers, we learned that the idea of tangible modeling is transferable to other process modeling notations. The tangible EPC model appeared to
be even more compact than the digital EPC because it could be overlooked at the table while the other model was hardly readable on a print-out.

Participants easily picked up the idea and started driving the modeling session. We have chosen the idea management department because they are familiar with interactive workshops and they had a need for clarifying discussions. We learned that this context welcomes the use of shared tangible media.

The tangible model also enabled a different quality of overview. The digital model would have been too large to be seen at once on the screen. On a three by one meter table all participants could see all aspects at a glance and browse them at will. We realized that standing, pointing and discussing alone are already important qualities achieved by such an overview. The tangible media adds additional value because it enables the participants to express ideas by directly interacting with the model.

The measures indicate that tangible modeling creates similar results when compared to the software-supported modeling technique in place (see figure 5.9, right). In terms of productivity, tangible modeling is even faster for smaller process models (see figure 5.9, left). Larger models benefit from a digital tool because it enables copying, pasting, and revising model parts. Recent studies indicate that an average of 14 percent of process model parts in repositories is truly redundant information [139]. It might be that process models become bigger than they need to be because it is so easy to produce large models with software tools.

We think productivity of tangible modeling is astonishing, especially because the additional software modeling tool expert is not required during tangible workshops. Moreover, the BPM expert in this case had hundreds of workshops of experience while TBPM was new for them. We might see further productivity gains through repetitive application of the tangible technique. However, we are aware that we compare one application of TBPM with a range of cases from a different department. Yet, all workshops were conducted by the same team of BPM experts.

We briefed the moderator about our existing method knowledge. Yet, our advice to do a warm-up exercise was ignored due to time constrains. Instead the moderator improvised a variant of his existing workshop technique. We reviewed both action research studies again and complemented existing best practice knowledge with new insights about setting and group facilitation. As examples, the modeling session should be well scoped. For example, whether to create an as-is or a to-be process model must be defined upfront.

5.4. Methodological guidance condensed

We summarize insights about TBPM modeling sessions for BPM experts that want to apply tangible modeling in their workshops. The guidance is embodied in method cards, covering eight aspects. The cards are a practical side-product of this research. They are designed to be brief and relevant for the target audience, experienced BPM experts.
Development of the method cards. We identify eight aspects for BPM experts to consider when using TBPM. First aspects were found in the first field study (see section 3.5) such as modeling guidelines and practical hints to accelerate process model creation. The first comprehensive method cards were designed after the first action research study, described in section 5.2.

The cards were iterated with more than twenty BPM modelers from practice and academia. They rated relevance of content and proposed improvements to the understandability. Thus, not all content in the method cards may have a corresponding scientific finding in this thesis. The method cards are practical artifacts. We briefly describe the identified aspects here. The original method cards (revision 7) are attached to this thesis in appendix A.11-14.

- **Fast Modeling:** We propose that people start by defining start- and endpoint of the process. Afterwards the main flow of activities is mapped. As the model is further detailed, a review for granularity should be performed. In other words, all activities should be on the same granularity to define a common level of abstraction. Importantly, the arrows should not be drawn on the table as long as possible to keep the process model easily changeable.

- **Modeling Guidelines:** We propose to use a minimum amount of concepts for modeling. Participants have to understand them, but less is easier to explain and shorter to kick-start the group. Special concepts may be introduced on the fly if needed. The facilitator should insist on meaningful labeling using ‘word object’ style. Bad labels are the start of fuzzy discussions. Similarly, each decision should be formulated as a question, which makes them more precise. Finally, the model should be as compact as possible with emphasis on importance, not on completeness.

- **Media Framework:** We propose a media framework that matches the tool with the purpose of the current modeling phase. Namely, people should generate models with TBPM, use software to archive models, review digital models on printouts, and use drawings to support conversations. However, we have also seen in section 5.2 that divergence from that framework can be useful.

- **Warm-up exercises:** We propose to model scenarios well-known from daily routines to get the group starting. Each scenario names the start, the end and some assumptions. Example, scenarios are ‘home ordering pizza’, ‘getting up in the morning’, and ‘withdrawing money from the ATM’. Using well-known but artificial scenarios gives every participant equal chances to contribute and enable modeling discussions without focusing on content already.

- **Setting:** We propose to invite 3-4 domain experts to participate in the workshop and facilitate the group with one or two BPM experts. While only one BPM expert is necessary to guide the group, it is more fun and less stressful to work with a partner. The room should have a large table with enough space to walk around it. Conference rooms are suited as they typically also have a stand-up display to draw or place overviews.
5. Field research with groups

session should be well scoped with objectives, timelines, and deliverables before it starts.

- **Project structure:** We propose a top down structure of the project which means we start with an overview. If many processes are involved, a process map should first be developed to collect them all. The important processes are identified and modeled. At first a high level of abstraction should be used. If required single steps are further refined in a separate model.

- **Iteration planning:** We propose to iterate a model multiple times. An iteration consists of four phases, (1) introduction, (2) modeling, (3) digitalization and (3) review. In the introduction phase the BPM expert sets the scope of the iteration and explains the concepts needed for the modeling phase. After the model is created with TBPM it is reproduced by a BPM expert in a software tool, called digitalization or archiving. This is typically done after the workshop. Reviewing the digital model on printouts is then the start point for the next workshop. That does not imply that TBPM models may not be directly reviewed during their creation.

- **Group facilitation:** We propose to communicate and enforce the modeling guidelines early. If necessary, the concepts for process modeling are explained multiple times. This pays off through more precise discussions and higher quality results. The group should keep moving around the table to develop new perspectives on the content. Furthermore, the facilitator should trigger the discussion of new aspects if the conversation gets stuck. The whole group should have one conversation at a time.

5.5. Critical discussion of action research findings

We used action research in this section to generate knowledge from field research. This method is not without critique in the scientific community since it does not fulfill the properties of traditional research.

**Data validity.** For outside researchers, it is very hard to judge on data validity [8] of action research studies. In contrast to video analysis, where the data is stored and can be reviewed by many other researchers, observational data gets filtered already when it is collected. To raise the quality of observations and the level of objectivity, we had two observers on side where possible. They independently noted information and discussed their notes. Yet, we are aware that there might have been an unconscious information filtering. The results from the quantitative evaluation are based on photos from the workshop progress and extracts from the organizational handbook.

**Generalizability.** Like the researcher, the client and the situational context is part of the data. Already choosing a client implies influences that limit the generalizability of the findings. The plurality of influences make it impossible to establish a causal
relationship between the action taken and the effect measured [87]. It limits the generalizability of findings from action research studies. In other words, the change implemented in one study might not cause the same effect in another study. Some researchers even suggest that the very nature of action research studies make it impossible to use findings separately from situational and even historical context [62].

**Action research is not Consulting.** Often, the action research method is mistaken for consulting by the client and the researchers alike. Baskerville maps out seven areas in which these methods differ in nature, see [6]. We implemented the tips by Baskerville to our best knowledge. In particular, it is the (1) motivation of the researcher to generate transferable knowledge, not money from consulting. It is the (2) commitment of the researcher to the client and the scientific community, not the client alone.

Furthermore, it is the (3) approach taken by the researcher to collaborate for knowledge creation, not to bring in outside expertise. The (4) foundations for recommendations by the researcher should be a theoretical framework, not empirical tradition. The (5) essence of the organizational understanding in action research comes from experimentation, not from critical analysis of the situation. The (6) explanations suggested by action research, are not universal in nature, but highly situational. And finally, the (7) client’s side benefits may not be existent in action research studies while consulting will always try to generate benefit for the client.

In our action research studies, we did not consult the BPM experts, we learned from observing them. We collected knowledge about the TBPM tool application and took measures to compare tangible modeling with other techniques of scientific investigations.

**Implications for the research findings.** We stress the point that action research is not without dispute in the scientific community. It is a research method that does not satisfy a key criterion of objectivist science [87], namely the detachment of observer and observed situation. Therefore, we warn readers to mistake the knowledge created in these studies as a covering law. The findings may be limited to the context in which they were created.

To address these inherent flaws, we make our observations and conclusions transparent for others to agree or challenge them. Furthermore, we do not claim to have found the only proper technique for all similar situations. Yet, we have found practices that have been perceived as useful in their context. We characterize the context to enable others to see opportunities for knowledge transfer to further fields of application but there is no guarantee that a proposed change will cause a specific effect.
5. Field research with groups

5.6. Summary of findings from field research

We started with the goal to make TBPM applicable in practice. In two action research studies, we investigated (1) when to apply TBPM, (2) how to apply TBPM, and (3) how it compares to established group modeling techniques in practice. In essence, the findings are as listed:

- **TBPM is useful if** processes need radical redesign and participants are willing to go into discussions. We contribute a longer sensitivity discussion in the paragraph below.

- **TBPM guidance requires** setting up the space, facilitating the group process, and empowering the participants to model correctly. We contribute guidance with method advice in eight categories (see section 5.4).

- **TBPM is as productive as** other group modeling workshop techniques. We compared the TBPM workshop productivity to software-supported group modeling workshops in section 5.3. We contribute a maturity discussion at the end of this section.

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**Sensitivity: When to apply TBPM.** TBPM is positioned to facilitate groups modeling processes together. It is a shared communication vehicle. In our studies, we used it in groups of one or two BPM experts and three to four domain experts. The participants should see a need to discuss with their colleagues and they should be open to the workshop style of working. Participant selection is a critical act for project success. We leave this aspect out of the discussion here and refer to [30, 43, 57, 125, 4, 124] for more information about the human factor for project success.

The business process and the workshop objective are key factors to identify candidates for TBPM workshops. If the process is not clear upfront because multiple stakeholders are required to create a big picture overview, TBPM can help to create this overview. Similarly, the redesign of a process might require the integration of multiple stakeholders and the creation of a mutually agreed business blueprint. The objective of TBPM workshops can be stakeholder integration, a shared common view, validation of or agreement to a plan. This is valuable especially when the organization is confronted with radical changes.

This characterization is by no means normative and TBPM might be used in many more contexts. Yet, there are also clear counter indicators for TBPM workshops. In particular, a well-established business process that does not require a radical redesign might not be suited for a TBPM workshop. In those cases, people know what they are doing and can talk very structured about their work. Often, the process is supported by IT-systems, which already automate parts of the process. This is often the case for core processes in well-established manufacturing industries such as the automotive industry.

**Method: How to apply TBPM.** We created practical guidance for BPM experts using TBPM with groups. The eight categories span advice for (1) fast modeling,
(2) modeling guidelines, (3) media framework, (4) warm-up exercises, (5) setting, (6) project structure, (7) iteration planning, and (8) group facilitation. These categories are explained in section 5.4 and embodied in method cards for practitioners (see appendix A.11-14).

Experienced BPM experts might ignore the advice entirely and run successful TBPM workshops by intuition. Indeed, some advice may even seem trivial to a BPM expert. Yet, we collected the guidance from field observations in which BPM experts forgot, e.g. to scope the modeling session to as-is vs. to-be models. The discussion got confused about this fact and we added this advice to the method cards. The card content was rated several times by practitioners and BPM researchers to derive a stable set of relevant information.

Limitations. We use observational research to create knowledge. By definition, there is no true objectivity [71] because it is not possible to detach the observer from the observations made. Wherever possible, we used two researchers observing independently and discussing their results afterwards. The outcome of these discussions formed the observations described here. Yet, not all aspects from a complex real world did make it into this thesis. Moreover, the research findings have not been validated the same way like the hypotheses in chapter 4. Consequently, we do not claim that the same change in a similar situation would result in the very same effect as described here.

Maturity: Closing the action research cycles. We concluded our field investigations after we found that TBPM is actually competitive in productivity and result. That does not mean, that there is no more to find out about TBPM application. Yet, given our research goal to make TBPM applicable in practice, we reached a reasonable closing point.

We have learned that TBPM models have characteristics similar to other models created by the same BPM experts in the same company. We also found that the modeling productivity of TBPM is acceptable for models that cannot profit from the copy-paste-revise patterns. We think the TBPM productivity is astonishing given that a single moderator could run the TBPM workshop. In contrast, the software-supported modeling workshops that we compared with in section 5.3, require an additional modeling tool operator.
6. Fields of application

We evaluated the effect of TBPM on individuals in chapter 4 and designed a methodology for the use of TBPM for a specific field of application in chapter 5. On top of this, we see potential for the use of tangible business process modeling in further areas. This chapter describes fields of application that we encountered during the journey of the design and evaluation of the TBPM technique. The scientific investigation was limited to one field of application (described in section 6.1), yet we share other application fields to work out commonalities and differences. It may help others to identify further fields of application for tangible (business process) modeling.

Commonalities. All fields of application described in this chapter share the need to discuss knowledge in groups from a process perspective. The groups come together because they require the contribution from different stakeholders to create a proper picture of the process. The TBPM tool functions as a frame by defining concepts to talk about. The evolving tangible process model reflects the shared state of the discussion. All users of the TBPM tool are novice or rare applicants of process modeling, so called non-professional modelers.

The findings described in chapter 4 about the effect of TBPM on individuals shall hold in all the fields of application described in this chapter. In particular, participants will be more activated to engage with the task. They will give more feedback and iterate more often over the process model created. Finally, they will build more understanding for the process that they discuss when using TBPM.

Differences. The application scenarios in which we used TBPM differ in key modeling aspects such as the objective of the modeling session, the participant background, and the degree of moderation. Consequently, the quality of the process that results from such a modeling workshop is different as well. We describe each field of application with a characterization and samples.
6. Fields of application

6.1. Domain experts in process elicitation workshops

Process elicitation and modeling workshops are the primary field of application for the TBPM technique. It was described and investigated in chapter 3 and chapter 5 of this thesis. The TBPM method was developed to guide business process modeling (BPM) experts that work with groups of domain experts in workshops to elicit process models as the result (see figure 6.1).

Figure 6.1. Process elicitation workshops with domain experts moderated by a BPM expert. As examples, doctors model clinical pathways in BPMN (left) or department employees model idea management processes using EPC notation (right).

Characteristics. These modeling workshops are moderated by an experienced BPM expert. Domain experts participate to share their knowledge and validate that it is adequately captured. After being introduced to the TBPM toolkit, domain experts create the process model themselves, discuss it with their peers and iterate it during the workshop session.

The objective of these modeling workshops is to generate process models for documentation, organizational change, or blueprints in software engineering projects. Therefore, process models need to describe the solution on an operational – not an abstract – level of detail and should be formally correct. We encountered this field of application in the field studies described in section 3.5, section 5.2, and section 5.3.
6.2. Educating business process modeling experts

People being educated in process modeling typically participate in process modeling trainings. Camunda\(^1\) – a company that offers process modeling training – contacted us to evaluate the use of TBPM in that field of application for themselves. We also tried this theme in the context of an introduction lecture to business process modeling at REFA\(^2\), a large educational corporation specialized on organizational management. Impressions from these trainings are depicted in figure 6.2.

![Process modeling training. As examples, TBPM used at Camunda with small tables (left) and at REFA with spacious room (right).](image)

**Figure 6.2.** Process modeling training. As examples, TBPM used at Camunda with small tables (left) and at REFA with spacious room (right).

**Characteristics.** The participants in these modeling sessions come from various background and had some introduction to process modeling by means of front lectures. The TBPM modeling typically is the very first hands-on modeling experience. They work in 3-4 groups with 3-4 participants each. The teacher walks around and may intervene to steer the modeling but in general, the participants in a group have to work out the correct model with the help of each other.

Process models created for training purposes may be on topics such as ‘pizza-ordering’ or ‘ATM withdrawal’. These are scenarios that all participants are equally aware of and can contribute to. We also proposed them as exercises in section 5.4. We actually took the inspiration for ‘pizza-ordering’ from the first training at Camunda.

The objective of the modeling exercise is to create a formally correct model and discuss modeling decisions. Thereby, people learn the skill of process modeling. The TBPM tool reduces the cognitive effort of the learners as discussed in section 2.2. Learning process modeling is separated from learning to use a particular modeling software.

The first application of TBPM for training was tested during the prototyping phase without the researchers being present. At that very early stage the use of TBPM was not a success for Camunda because the training area did not provide enough space for the groups to model (see figure 6.2, left). We fixed this later in

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\(^1\)http://www.camunda.de

\(^2\)http://www.refa-berlin.de/
the method guide by adding a requirement for spacious rooms and tables. We also learned that guidance is needed even for experienced process modeling trainers using TBPM for the first time. The application at REFA (see figure 6.2, right) was successful with enough space and very positive feedback from the participants. This application was at the end of the research journey.

6.3. User researchers simulating costumer experiences

User-friendly service design has become a competitive advantage. Some companies specialize in user research for new products or services. In this context, the user researchers conduct field observations and meet afterwards to share and validate their understanding of the user experience. Various tools, such as persona building and vision statements are used to create this understanding together. TBPM can be used to map the user experience as a process and simulate it. We prototyped this field of application together with D-Labs\(^3\), a user-centered design agency, and at a user-centered innovation conference\(^4\). Photos from these applications are depicted in figure 6.3.

![Figure 6.3](image)

**Figure 6.3.** User researchers model and simulate customer experiences as processes. As examples, in a facilitated group at a user-centered design agency (left) or in a self-managed group at a user-centered innovation conference (right).

**Characteristics.** The participants of such a workshop are user researchers or user experience experts. They may have a formal background from math or computer science but typically no background in process modeling. They are facilitated by a BPM expert to frame their knowledge or act as self-managed teams.

The objective of the modeling session is to discuss many scenarios. The process mapping helps them to articulate customer needs and expectations from the process perspective. Therefore they simulate scenarios based on the shared model. The resulting process may be used as part of the documentation for the service design. However, the process model is not necessarily correct from a formal modeling perspective.

\(^3\)http://www.d-labs.com/

\(^4\)http://spewire.sdu.dk/pinc/
6.4. Design thinkers ideating future services

Design Thinking is an innovation method that encourages prototyping as one aspect of the design process. The scenarios to design for are placed in ten to twenty years from the current date. Envisioning is necessary to describe the future solution. A process-oriented viewpoint can help to raise issues regarding the value chain that enables the fulfillment of a new service. We used TBPM together with ME310 students at University St. Gallen, the global team-based design innovation class. We also prototyped this field of application with students at the HPI school of Design Thinking in Potsdam. The application in St. Gallen and Potsdam is depicted in figure 6.4.

Figure 6.4. Design thinkers envisioning services for the far future using TBPM. As examples, ME310 students at the University St. Gallen (left) and students at the HPI school of Design Thinking (right).

Characteristics. The participant background is heterogeneous by nature in those teams. They are typically not facilitated by a process modeling expert but get a short introduction to TBPM and work it out from there by themselves. The objective of the session is to envision and build on the ideas of others. The TBPM tool provides a basic framework of concepts to talk about. That framework might be extended by the participants if needed. For example, desires, pain points, or flying cars are not part of process modeling but may be needed to describe a future scenario. This field of application is similar to the one described in section 6.3 but the applicants are explicitly not bound to rules of modeling. Instead they are encouraged to break rules to see beyond and get inspired. The process models from these sessions are barely used afterwards. The value proposition here is in the discussion at the table, not in the modeling result. Insights gained might lead the project into new directions.

5http://me310.stanford.edu/
6http://www.hpi.uni-potsdam.de/d_school/home.html
6. Fields of application

6.5. Strategy and service design consulting

Strategy design is the definition of a preferable future for an organization. Service design is the definition of this future from a customer perspective. The difference to the service design described in section 6.3 or section 6.4 is that the organization delivering the service also designs the service itself according to its strategy. The external expert is a facilitator to help the organization define those strategies and services.

We met John Body, the founder of Thinkplace\(^7\), a design-thinking-oriented consulting firm. Thinkplace consults companies and government agencies that work out their strategy and services. Their specialty is empowering the clients to work out their solution for themselves. Instead of bringing in external advice, they bring in tools for communication to the organization. After we met, John Body adopted the idea of tangible modeling for processes and other frameworks of thinking (see figure 6.5).

![Figure 6.5. Strategy and service design using tangible tiles. As an example, Thinkplace consults organizations in strategy and service design using their own interpretation of tangible process modeling.](image)

**Characteristics.** Participants in those workshops are managers and domain experts of the company or government agency. One or more moderators from the consulting company facilitate the group. The workshops last for days and concern the building of various views on the organization’s strategy and services. Process modeling is one among many views with the objective to build one more perspective on the to-be situation. The perspective might be customer experience processes similar to the ones described in section 6.3 or back-end processes of the organization. The models and findings from these workshops are used for organizational development.

\(^7\)http://thinkplace.com.au/
6.6. Summary of application fields

We developed TBPM as an alternative workshop technique for BPM experts who want to co-create process models together with their clients, the domain experts. Nevertheless, the idea of tangible modeling was adopted by others and transported even beyond processes (see section 6.5). TBPM turned out to be useful for process modeling trainings (see section 6.2). Moreover, it works as a creativity tool for people outside the process modeling area. The applicants benefit from framing their discussions into basic process concepts while maintaining large degrees of freedom to present arbitrary information (see section 6.4 and section 6.5) such as pain-points and needs.

The application fields described in this chapter do not represent a closed set of options. They rather represent reinterpretations of the TBPM idea and they open the eyes for further opportunities. All existing fields of application have in common that they are group workshops. The participants gather to discuss ideas and create a process model that represents their shared understanding. The application of tangible modeling to strategy workshops in section 6.5 indicates further opportunities even beyond process modeling. We discuss the transportability of our research to further areas as part of the concluding chapter 7.
7. Conclusion

This thesis is motivated by the observation that process modeling is a skill for specially trained people, the business process modeling (BPM) experts. They elicit process information in interviews or workshops from clerks or managers, the experts of the domain. The process model is created by the BPM expert with a dedicated software tool. Using the software requires special training and experience. The domain experts – those who have the process knowledge in the organization – are left out in the core task, the creation of models.

This practice decouples the process owners from the process models. The domain experts are limited to provide feedback to an artifact created by people with limited domain knowledge. If the domain experts do not agree with the information embodied in the process model, they cannot instantly change it. They have to provide feedback and channel the change through the BPM expert. Some mistakes might never be corrected as a result of this indirection. We have changed this practice of separation between those that know and those that model. Our journey starts with a research objective and a set of goals.

7.1. Research objective and goals revisited

We set the research objective to ‘design and evaluate an approach to engage domain experts in the creation and validation of their process models’. To meet this objective, we created a tangible toolkit – called TBPM – that can be used by a group of people to model processes at a table. The modeling expert facilitates the domain experts in the creation of their models. To guide the tool application, we developed method guidance for the BPM experts. In an experiment, we found that TBPM modeling leads to more validated modeling results. We further sharpened our research objective with three goals to be tackled:

- **Create a group modeling experience:** We prototyped and explored group modeling experiences in chapter 3. We tried role-games until we got a spin towards tangible modeling that led to the creation of TBPM. The creation of method guidance in chapter 5 also contributes to the goal of designing a group experience.

- **Compare the solution to existing approaches:** We compare TBPM to structured interviews in chapter 4 and to software-supported modeling workshops in chapter 5. These are the most commonly used elicitation methods in practice.
7. Conclusion

☐ **Ensure the solution is applicable in practice:** The first professional application was already conducted during early investigations in chapter 3. We devote an entire research phase in chapter 5 to the development and evaluation of the practical applicability. Compared to software-supported workshops, we found a competitive modeling speed and result.

With tangible business process modeling (TBPM), we have found one possible way to meet the research objective. We have evaluated TBPM by comparing it with interviews and software-supported workshops as the most commonly used elicitation methods in BPM practice. More research would be possible such as comparing to brown-paper modeling or the collaborative software modeling idea by Rittgen [111]. We decided to conclude by ensuring that our solution is meaningful to practice according to our goal. We discuss further research opportunities in section 7.5.

7.2. Research Methods revisited

Our research agenda embraced design and evaluation in fast iterations to rapidly test ideas and enable fast feedback. The agenda can best be approximated by the design science research framework (see figure A.2 and figure A.4 according to [60] and [148]). Design science research proposes to iteratively build an artifact and evaluate it. Our artifact is the TBPM technique, consisting of toolkit and method. The building process was inspired by related research on requirements elicitation, group modeling, cognitive theories, and design research (see chapter 2). The evaluation was conducted in three steps: We have investigated the technique in exploratory studies, a laboratory experiment with individuals, and with groups in real project settings.

**Exploratory studies.** We conducted a series of studies in which we tried TBPM modeling with office assistants, IT students and hospital doctors.

The first study compared process elicitation with different media. We interviewed six office assistants using no media (structured interview), TBPM process modeling, or Post-Its. In the next study, we invited freshmen IT students to participate in either an interview or a TBPM modeling session. This study became a pre-study towards the controlled laboratory experiment performed later. Finally, we conducted a case study in the field in which an experienced consultant used the TBPM tool to moderate a one week workshop with hospital doctors. That became the first step towards methodology development for groups.

**Controlled experiment with individuals.** In a laboratory experiment we determined the effects of TBPM on individuals. The experiment was conducted with seventeen student clerks from a trade school. They served as proxies for the generalized population of domain users. By comparing TBPM modeling with interviews, we found that subjects are more engaged and create more validated results. The experiment enabled findings with statistically significant probability. It means
that the observed effects are true for more than 95 percent of the generalized population.

**Field research with groups.** We decided to team up with consultants to develop TBPM for practical application with practitioners. We worked with two partners using action research to create method guidance for BPM experts and a characterization of situations that welcome the use of TBPM workshops. We concluded our research after we had a stable opinion on the method and measures indicated that TBPM is at least as useful in practice as established techniques.

### 7.3. Overview of Findings

We investigated TBPM modeling in various situations. For summary, we frame the findings into four categories, (1) method guidance for BPM experts, (2) the suitable context for TBPM application, (3) the effect of the tool on people and (4) the effect on the process model.

**Method.** We propose to apply TBPM in workshops with groups of people. A warm-up exercise is useful to practice modeling with a well-known scenario before starting with the actual process to be modeled. After deciding on start- and end-point for the process, the main activities get mapped and the process model is iteratively refined from there. Throughout the workshop, a BPM expert facilitates the group and ensures that the process modeling rules are respected.

Method guidance for the moderator was developed together with practitioners and synthesized in method cards. The cards span the aspects of modeling guidelines, setting, group facilitation, media framework, warm-up exercises, project structure, and fast modeling, see appendix A.11-14.

**Context.** TBPM is designed to facilitate groups modeling processes together. The participants should see a need to discuss with their colleagues, for example the design of a new process that they all have stake in. TBPM can help integrate all stakeholders and create agreement. In contrast, TBPM is not expected to be helpful for well-established and well-structured processes with limited potential for improvement. Those processes are often already software-supported with little divergence in stakeholder opinions.

**Effect on people.** Process models are maps to the people that have created them. In exploratory studies, we observed people navigating through their knowledge after framing it into the concepts of process modeling. When comparing TBPM to interviews in the experiment, we found that participants have more fun and build more understanding for the process with TBPM. Additionally, they spend more time talking and thinking about their process. We concluded that TBPM engages people with the act of process modeling. Throughout all studies, the participants indicated to enjoy TBPM modeling.
7. Conclusion

Effect on process models. The TBPM process model gets more often reviewed and corrected by the participants, as we found in the laboratory experiment comparing TBPM with interviews. We summarize these observations as more feedback and conclude that this leads to more validated results. Although the tangible process on the table is large – compared to a print-outs – it enables a compact overview even for larger models that would otherwise be scattered over multiple printed pages. We found in field studies that TBPM models are comparable to other models in terms of size and reflected aspects. In other words, TBPM does not create different models, yet it creates more validated as we found in the experiment.

7.4. Contributions

Our contribution is twofold, practical results and scientific findings. The practical results are a set of plastic shapes used to model processes – the TBPM toolkit – and a method to guide BPM experts using the TBPM toolkit in workshops with non-professional modelers. The tool and the method together form the TBPM technique. Literature review, and the investigation of the TBPM technique lead to the scientific contributions:

- A set of principles for the work on conceptual models together with domain experts. This is based on a review of scientific literature from cognitive science and design research in chapter 2. We propose to map out information, choose an expressive representation and make it easy to use. Furthermore, we propose to choose media with affordances that support the purpose of the model according to the media models theory.

- A comparison of tangible process modeling with interviews. This is based on a controlled experiment with seventeen student clerks. We found that tangible modeling leads to more engagement through activation of participants and to better validated models through more reviews and corrections.

- Methodological guidance for BPM experts conducting tangible group modeling workshops and a description of qualities that promote the use of tangible process modeling. This is based on case studies and action research. The methodological guidance covers eight aspects and was also the basis for the TBPM method cards (see appendix A.11-14).

- A comparison of established software-supported modeling workshops with TBPM modeling workshops. The data is collected in collaboration with practitioners using the action research method. Productivity and result of TBPM workshops are competitive given a suitable context.

7.5. Further research opportunities.

The research on tangible business process modeling (TBPM) concluded but it also pointed at more fields for research. Building on our findings, further research may go into the following directions:
7.6. Concluding discussion

- **More experiments with novice modelers:** Comparing groups in changing conditions can help to better understand the facilitation of non-professional modelers when framing their information. We compared here interviews with tangible modeling. Yet, more fine-grained experiments may help to unravel the benefits that Post-Its or free-hand drawings may provide over interviews and how they are different from tangible modeling.

- **Tested metrics for workshop comparison:** Graph metrics are typically used to characterize process models. By now, there is only little knowledge about the correlation of these metrics with content or effects of the process model. One exception is the PhD work by Jan Mendling that correlated these metrics with error probability [91] in process models. Similar effort is needed to discover and validate metrics to approximate productivity and outcome of modeling workshops.

- **Comparing BPM workshop techniques:** Based on proper metrics, existing BPM workshop techniques could be evaluated. Best practice workshop techniques exist in industry but they are barely shared or even compared. There is opportunity to compare workshop techniques and determine successful patterns for cooperation of BPM experts and their clients.

- **User-driven modeling techniques:** We have shown that it is possible to guide users in creating models useful to software engineering. It is to be determined how far this can be taken and were it ends. Other modeling techniques like UML, Entity-Relationship Diagrams or IT Architectures might also be created by users using tangible objects or other easily accessible tools.

### 7.6. Concluding discussion

This work changed the role of the BPM experts. Instead of eliciting information and framing it into a process model himself, the BPM expert became the facilitator of the process model creation conducted by the domain experts. With the tangible business process modeling toolkit and method, we have created a technique that can be used to engage the knowledge carriers – the experts of the domain – to create their process models with their own hands. Intuitive tooling combined with an appropriate guidance creates more user engagement and validated results.

**Maturity.** Advancing a modeling technique is a never ending story. Experience builds up with every workshop. New situations are encountered and answers are found to previously untapped questions. Yet, the learning curve flattens over time.

We iterated the method cards with BPM experts. After some iterations, only minor change comments have been made and the overall satisfaction with the artifact grew. In our second field study (see section 5.3) we compared the TBPM workshop productivity and results with software-supported workshops and found
the numbers competitive. Thus, we think the technique is mature enough to compete in the field. That puts the spotlight on other situational success factors [124], such as management support.

It does not imply that there are no research opportunities left (see section 7.5) but given our research goals we reached a reasonably mature point.

**Generalizability.** We investigated one specific type of modeling, business process modeling. We encountered increased engagement and validated results with tangible models. The laboratory experiment was based on BPMN but in field studies we extended the notational scope to EPC without any drawbacks. Therefore, we see no indication that the findings are limited to a specific process modeling language. Even more, we think it is possible to transport the positive effects to more modeling notations even beyond the world of business processes.

In other words, the most general contribution of this research is to show that it is possible to involve domain experts – non-professional modelers – into model building by providing a suitable tool and facilitation. The principles that we derived from literature in section 2.6 are not specific to process modeling either. They should apply to other modeling techniques as well. One example of a new field for application is the company Thinkplace that adopted tangible modeling to strategy workshops as explained in section 6.5. Researchers that follow our path to model with domain experts may build on our findings from the exploratory studies, the laboratory experiment, and the field research. Yet, our implementation of these research methods are not without limitations.

**Limitations.** All research findings are situational. This thesis has context assumptions, such as a problem worth discussing amongst the people at the table and a BPM expert as facilitator. If assumptions about the context change, the findings have to be re-evaluated.

The findings from the exploratory studies and action research have no aspiration of completeness. For example, we created the method guidance for practitioners from action research studies with experienced BPM experts but that does not mean the method guidance contains all relevant information to run a successful workshop. Group facilitation knowledge, e.g. about the best way to create a fruitful conversation, is not covered.

The controlled experiment helped to validate the effects to be expected within people using TBPM. Rigorously speaking, it only makes a statement in comparison to interviews or TBPM modeling in single person situations. In general, effects within individuals will also occur in groups but additional group effects may superpose effects within individuals. That was not investigated. The operational shortcomings in our experiment are discussed in section 4.4.1 as well as why they do not harm our overall findings.

**Final remarks.** Of course, a research journey is not as straight as the argumentation in the final publication. The initial journey was steered through radical pivots which eventually led to the discovery of tangible modeling as an idea. To get there
we had to go beyond some assumptions about our role as software engineers and BPM researchers.

The result is groundbreaking in two ways. For one, TBPM engages a new audience – the domain expert – directly in model building. It thereby changes the role understanding in requirements engineering. Now, domain experts create models, discuss them, and apply changes directly. The modeling expert becomes a facilitator of that process. Second, as software engineers, we struggled at first when we learned that many people do not want to engage with the modeling software we build. The first reaction was: We need better software! It took courage to leave this pattern behind and realize that the solution maybe outside of our comfort zone.


Bibliography


The appendix contains additional information that may be valuable for interested readers. The following information can be found:

- The design science research frameworks as visualized by Hevner in figure A.1 and Wieringa in figure A.3. Additionally, visualizations of this thesis in the light of these frameworks in figure A.2 and figure A.4.

- The original material used for the controlled experiment in chapter 4 is displayed in figure A.5, figure A.6, figure A.7, figure A.8, figure A.9 and figure A.10.

- The TBPM method cards are shown in figure A.11, figure A.12, figure A.13 and figure A.14.
Figure A.1. Information systems research framework for design science research by Hevner taken from [60], page 9.
Additions to the Knowledge Base

Environment

People
- domain experts (modeling novices)
- process consultant (modeling expert)

Organizations
- BPM driven projects (IT/business)

Technology
- Post-Its
- software tools
- structured interviews
- workshops

Relevance

Develop / Build
- TBPM toolkit
- workshop guidance

Need: user engagement
Assess
Justify / Evaluate
- prototyping
- case studies
- controlled experiment
- action research
Refine

Rigor

Knowledge: how to model, engage, ...

Knowledge Base

Foundations
- BPM Research
- Design Research
- Cognitive Science
- BPMN/EPCs
- ...

Methodologies
- statistical analysis
- questionnaires
- video analysis
- process metrics
- interviews

Implemented at:
hospitals, energy provider, trainings, d.schools, UX design companies

Knowledge played back:
(1) principles for modeling with novices
(2) effect of tangibles in process modeling
(3) guidance for tangible group modeling sessions
(4) comparison of group modeling techniques

Figure A.2. This thesis framed as design science research according to Hevner [60]
A. Appended material

Figure A.3. Information systems research framework for design science research by Wieringa taken from [148], page 65.

Figure A.4. This thesis framed as design science research according to Wieringa [148]
**Der Begriff Geschäftsprozessmanagement**

Geschäftsprozessmanagement ist ein ganzheitlicher Ansatz zur Optimierung der Abläufe im Unternehmen. Diese Abläufe können das Eintreffen neuer Waren oder das Bezahlen von Mitarbeitern sein. Diese Methodik ist nicht auf Unternehmensbereiche begrenzt sondern versucht die Wertschöpfung im Unternehmen nachzuvollziehen. Das Ziel ist das Unternehmen effektiver zu machen, indem man die Abläufe besser versteht und optimiert. Im unten stehenden Bild werden die Phasen des Prozesslebenszyklus beschrieben.

![Prozesslebenszyklus](image)

**Bild1: Geschäftsprozesslebenszyklus**

(Process Management Lifecycle)

Im ersten Schritt werden die Prozesse analysiert (Process Analysis). Die Frage ist „Wer macht was, wann, wie und womit?“. Man bezeichnet dies als den Ist-Prozess. Es ist die aktuell gelebte Realität. Im zweiten Schritt wird der neue, optimierte Prozess entworfen. Es ist der Soll-Prozess. Hier wird der gewünschte Zustand beschrieben. Dabei wird der Prozess mit allen Beteiligten diskutiert um mögliche Probleme oder Optimierungsmöglichkeiten zu identifizieren.


*Figure A.5. Experiment Material: BPM introduction used to condition participants, part 1/2*
Das Prozessmodell als zentrales Arbeitsmittel


![Prozessmodell Darstellung](image)

Bild2: Aspekte von Prozessmodellierung

Iederweise werden die Prozessmodelle in allen Phasen als Kommunikationsmittel eingesetzt. Modelle können außerdem genutzt werden um Prozesse zu simulieren und so neue Abläufe vorher zu testen. Die Modelle werden auch als Vorlage bei der Softwareentwicklung eingesetzt oder dienen als graphisches Konfigurationswerkzeug für Standardsoftware.

Die Arbeit des Lehrstuhls

Der Lehrstuhl für Business Process Technology lehrt und forscht in allen Bereichen des Prozesslebenszyklus. Im Besonderen geht es darum wie Prozessmodelle in Software- systemen eingesetzt werden können um Prozesse zu entwerfen, zu simulieren, umzusetzen und zu überwachen.

Figure A.6. Experiment Material: BPM introduction used to condition participants, part 2/2
Beispiel für ein Prozessmodell

Legende der Symbole

- **Start**
- **Ende**
- **Aktivität**

- **Sequenzfluss**
  Pfad der Ausführung (Reihenfolge)

- **Datensymbol**
  Dokumente oder Informationen die für Aktivitäten relevant sind.

- **Parallelles Gateway**
  ermöglicht gleichzeitiges Ausführen von Aktivitäten auf mehreren Pfaden.

- **Exklusives Gateway**
  ist eine Unterscheidung zwischen Ausführungspfaden, d.h. nur einer der folgenden Pfade wird ausgeführt.

Optimale Modellierung

- In Modellen werden oft nur die häufigsten Fälle abgebildet. Als Daumenregel gilt, dass 80% der realen Prozesse mit dem Model erfasst werden sollten.

- Zur besseren Lesbarkeit werden Aktivitäten mit *Objekt Verb* benannt werden, z.B. *Tisch decken* oder *Wasser erhitzen*.


- Entscheidungskriterien werden an die ausgehenden Pfade des exklusiven Gateways notiert (siehe Beispiel: *alleine Essen* vs. *Besuch*).

Figure A.7. Experiment Material: BPMN Sample sheet used to familiarize participants with process models.
Kauf eines neuen Großbildschirms für den Eingangsbereich

**Die Aufgabe**
Der Unternehmenschef möchte Werbefilme im Foyer des Unternehmens laufen lassen. Dazu soll ein großer Bildschirm (mindestens 80") gekauft werden. Sie sind für die Beschaffung und Abrechnung des Bildschirms zuständig. Sie sind nicht für den Werbefilm oder die Installation im Foyer zuständig. Schildern Sie die Schritte die notwendig sind. Beginnen Sie mit dem Moment indem Ihr Chef Ihnen die neue Aufgabe übertragen hat. Enden Sie, wenn alle Rechnungen bezahlt und abgeheftet sind. Wenn die Aufgabe Spielraum lässt, dann treffen sie sinnvolle Annahmen.

Ausschreibung eines neuen Lagergebäudes

**Die Aufgabe**
Die Firma expandiert. Ihr Chef möchte ein neues Lagergebäude für Reifen auf dem Werksgelände errichten lassen. Es sollen Angebote verschiedener Baufirmen eingeholt und verglichen werden. Sie sind für die Ausschreibung und die Begleitung des Projektes zuständig. Beginnen Sie in dem Moment indem Ihr Chef Ihnen die neue Aufgabe übertragen hat. Ihre Beteiligung endet, wenn das Gebäude eingeweiht ist.

*Figure A.8.* Experiment Material: Introduction to the experimental tasks (two alternative scenarios).
Interview Guide:

Students get asked the following questions in exactly this wording and order by the experimenter:

- Frage1: Versuche alle relevanten Schritte zu identifizieren
- Frage2: Welche Dokumente spielen eine Rolle?
- Frage3: Gibt es grobe Phasen in deinem Vorgehen, die du identifizieren kannst?
- Frage4: Gibt es Schritte die nicht von einander abhängen so dass die Reihenfolge der Ausführung eigentlich egal ist, sie könnten also parallel ausgeführt werden?
- Frage5: Welche Probleme erwartest du bei diesem Prozess?
- Frage6: Gibt es noch etwas, dass du uns über diesen Prozess mitteilen möchtest?

When asked a question from the subjects. The experimenter shall use one of the following answers (if applicable):

- "Triff eine Annahme und gehe von dort weiter."
- "Dazu gibt es vielleicht Hinweise in der Aufgabenstellung"
- "Dazu gibt es vielleicht Modellierungshinweise"
- "Das weiß ich nicht."

Figure A.9. Experiment Material: Interview guide used by the experimenter to run the experimental tasks.
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Statement</th>
<th>Annotation</th>
<th>Stimme voll zu</th>
<th>Stimme eher zu</th>
<th>Teils / teils</th>
<th>Stimme eher nicht</th>
<th>Stimme gar nicht zu</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ich konnte in der Feedback-Phase wichtige Anmerkungen machen.</td>
<td>Annotation: not discussed in this thesis</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2</td>
<td>Ich konnte mich für diese Methode der Prozesserhebung begeistern.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3</td>
<td>Diese Methode hat nichts zu meinem Wissen über Prozesse beigetragen.</td>
<td>Annotation: related to Hypothesis 9 (understanding)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4</td>
<td>Ich war motiviert, die Aufgabe zu erfüllen.</td>
<td>Annotation: related to Hypothesis 4 (motivation)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5</td>
<td>Ich bin mit meiner Lösung unzufrieden.</td>
<td>Annotation: related to Hypothesis 5 (commitment)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6</td>
<td>Mir war klar, was von mir erwartet wird.</td>
<td>Annotation: related to Hypothesis 8 (clarity)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7</td>
<td>Ich würde nicht noch einmal am Experiment teilnehmen.</td>
<td>Annotation: related to Hypothesis 4 (motivation)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8</td>
<td>Ich war mir bewusst, auf was die Aufgabe hinausläuft.</td>
<td>Annotation: related to Hypothesis 8 (clarity)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9</td>
<td>Ich habe durch diese Methode etwas über Prozesse dazugelernt.</td>
<td>Annotation: related to Hypothesis 9 (understanding)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10</td>
<td>Mir war es wichtig, in der Feedback-Phase mein Wissen über den Prozess einfließen zu lassen.</td>
<td>Annotation: not discussed in this thesis</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11</td>
<td>Es war mir egal, ob ich die Aufgabe gut löse oder nicht.</td>
<td>Annotation: related to Hypothesis 4 (motivation)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12</td>
<td>Ich konnte durch diese Methode mein generelles Prozessverständnis verbessern.</td>
<td>Annotation: related to Hypothesis 9 (understanding)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13</td>
<td>Ich bin von meiner Lösung überzeugt.</td>
<td>Annotation: related to Hypothesis 5 (commitment)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14</td>
<td>Diese Methode hat mir Spaß gemacht.</td>
<td>Annotation: related to Hypothesis 3 (fun)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15</td>
<td>Mir war nicht immer klar, was genau ich tun soll.</td>
<td>Annotation: related to Hypothesis 8 (clarity)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>16</td>
<td>Die Feedback-Phase empfand ich als unnötig.</td>
<td>Annotation: not discussed in this thesis</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>17</td>
<td>Meine Lösung ist korrekt.</td>
<td>Annotation: related to Hypothesis 5 (commitment)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>18</td>
<td>Diese Methode empfand ich als nervig.</td>
<td>Annotation: related to Hypothesis 3 (fun)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Figure A.10.** Experiment Material: Questionnaire document used after the experimental tasks. Three statements together operationalize one hypothesis.
**Iteration Planning**

**How to structure the modeling project?**

- **Introduce**
  Modeling is done in iterations. Define a goal in each iteration. Introduce modeling concepts needed for the next modeling phase.

- **Model**
  Create a shared understanding. Discuss and rework the model until all participants agree on the result.

- **Digitalize**
  Take a photo of the model when you are done. Transfer it to a software tool at home. Correct only obvious mistakes and do not change the model layout or meaning.

- **Review**
  Develop a natural distance to the model by letting time pass. Afterwards gather with the group and review it. Iterate or approve it.

---

**Project Structure**

**How to deep dive without losing context?**

- **Capture the process landscape**
  If multiple processes are involved, collect and organize them first. Afterwards decide which process you are going to model.

- **Create the big picture process**
  Model the simplest case that everybody can agree on to have a starting point for discussions.

- **Drill down**
  Decide together on the relevant aspects to further specify. Model them on the next level.

- **Enrich concepts**
  Enrich the model with roles, data and exceptions. Only add information that are relevant for the current iteration.

---

*Figure A.11. TBPM method cards on iteration planning and project structure.*
Media Framework
How to match media with purpose?

- Generate models using t.BPM
  Everybody must be able to contribute to the process creation. Use t.BPM to create and discuss the process model together.

- Review models on printouts
  Printouts indicate a formal document. They invite critical reviews and offer enough blank space for comments.

- Use software to store models
  Software tools are great to store and find models. Digitalize your t.BPM models regularly but don’t get distracted by software during modeling sessions.

- Use drawings in conversations
  Drawings visualize thoughts and help all participants to follow conversations more easily. It also allows to literally point out an aspect within a context.

Setting
How to set up a t.BPM session?

- Invite 3-4 participants
  Get domain experts that have a role in this process and want to contribute their view. Avoid observers and hierarchies within the group. Facilitate the group with 1-2 moderators.

- Provide enough space
  Organize a conference table to model and at least 4 times as much space to walk around.

- Have a stand-up display ready
  Whiteboards and flipcharts are well suited to discuss and display context information such as documents and model printouts.

- Scope your session
  Do you model the process as it is or as it should be? What is the goal of this session? Communicate timetables and plannings. Give everyone a pen.

Figure A.12. TBPM method cards on media framework and setting.
Warm-up Exercises
How to get participants into the mood?

- Use well-known scenarios initially
  Model a daily situation that every participant is equally aware of. This is a good opportunity to discuss process modeling without putting results at stake.

- Exercise: home order pizza
  Starts by choosing from an available menu and ends when you close the door behind the delivery boy. Assume you order via phone.

- Exercise: get up in the morning
  Starts with your alarm clock ringing and ends when you leave the house. Assume it is a typical work day.

- Exercise: withdraw money from ATM
  Starts at the ATM with your cash card at hand and ends when you have the money and your card back. Assume there is enough money on your account.

Group Facilitation
How to make the team work?

- Communicate rules
  Put up an agenda for each session. Set short time frames for each phase. When modeling, enforce the correct use of modeling elements from the start. Intervene and explain rules twice if necessary.

- Keep moving
  Standing at and moving around the table creates team dynamics and new perspectives.

- Raise triggers
  If the conversation gets stuck or settles, raise a new issue to vitalize the discussion. You may add further aspects or review the existing process from a different perspective.

- Foster one conversation at a time
  Arguments are missed and the group dynamics collapses if different discussions are going on in parallel.

Figure A.13. TBPM method cards on warm-up exercises and group facilitation.
### Modeling Guidelines

**What to consider beyond syntactic correctness?**

- **Use minimum amount of concepts**
  
  You can express many situations and create a vital discussion with only few modeling concepts. Start with activities, events and decisions. Introduce further concepts whenever required.

- **Insist on meaningful labeling**
  
  Invest in discussions to find appropriate labels. It will reveal misunderstandings and help to build a common terminology.

- **Make each decision a question**
  
  Alternative paths are best labeled with a clear question that can be answered yes/no. Each path gets labeled with an unambiguous answer.

- **Create compact models**
  
  Large tables invite detailed process models. But a model can only reflect parts of the reality. Concentrate on aspects that support your modeling goal. Go for importance, not for completeness.

---

### Fast Modeling

**How to accelerate process creation?**

- **Define process start and end**
  
  Agree on the process scope by naming your start- and end-event. Frame the modeling space by positioning the events on the table.

- **Concentrate on main flow**
  
  Concentrate on things that happen in most cases. Step in if discussions drift to exceptional situations. Don’t get lost in details that add complexity only.

- **Keep shapes floating**
  
  Lay out shapes from left to right to indicate the order between activities. Defer drawing arrows to the end to keep the model flexible.

- **Review granularity**
  
  Agree on a consistent abstraction for all activities. After the process is first mapped the model may need adjustments to harmonize the level of granularity.

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*Figure A.14.* TBPM method cards on modeling guidelines and fast modeling.