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Kumulative Habilitationsschrift

Facilitating organizational alignment through people-centric articulation of knowledge about work

angefertigt zum Zwecke der
Erlangung der Lehrbefugnis im Fach

Wirtschaftsinformatik

von

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to Lisa, Felix & Sabrina

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1 Introduction

Human work in organizations is an inherently collaborative phenomenon. People rely on information or goods provided by others and in turn are required to provide others with the results of their work. In order to collaborate successfully, the involved actors need to develop a shared understanding of their work processes (Škerlavaj et al. 2007; Stary 2014) and to align their mutual expectations on how to interact with each other (Strauss 1988; Larsson 2003; Van Boven & Thompson 2003). This shared understanding and these expectations need to be reflected in an organization's information systems architecture (Jonkers et al. 2006) in a way that enables effective support of the respective work processes (Baxter & Sommerville 2011). *The work carried out in the course of this cumulative habilitation thesis strives to provide instruments facilitating **articulation processes** among collaborating actors. This support should lead to syntactically correct and semantically sound **conceptual models** for alignment with an existing **enterprise architecture**.*

The efforts dedicated to reach this aim have led to **scientific contributions** in three areas of research:

Articulation of organizational work is an area of research concerned with stakeholder involvement in organizational development processes (Arias & G. Fischer 2000; Adamides & Karacapilidis 2006; Kaghan & Lounsbury 2006; Roberts 2009). It aims at actively engaging operative personnel in change projects affecting work processes to facilitate the development about a shared understanding of as-is and to-be work structures and processes (Vennix et al. 1996). This ultimately should avoid ineffective work routines and unclear responsibilities, and at the same time enable the design of appropriate socio-technical support measures (Herrmann et al. 2002). The first contribution of this thesis to this field is a design theory on multi-perspective articulation and consolidation of knowledge about organizational work and its interactive elaboration to develop technically processable representations about work processes (Oppl 2016a). As a second contribution, the design theory has been instantiated in a methodology to support business process elicitation, ultimately generating representations that can be processed in workflow management systems (Oppl & Alexopoulou 2016).

Collaborative conceptual modeling is used as an enabler for the aforementioned contributions. Research in this field in the last years has focused on how modelers can be supported during the process collaboratively representing their understanding about the subject of modeling in a single conceptual model (Niehaves & Plattfaut 2011; Rittgen 2010; Aleem et al. 2012; Barjis et al. 2009). Particular effort has been dedicated to enable the active involvement of domain experts not formally educated in conceptual modeling, allowing them to directly incorporating their knowledge in the model (Santoro et al. 2010; Hoppenbrouwers & Rouwette 2012). The first contribution of this thesis to this field is a set of scaffolding-based guidance measures for collaborative modeling by people without any background knowledge or experiences in conceptual modeling (Oppl 2016d). The effects of these guidance measures have been empirically validated using a methodological approach for evaluating collaborative modeling processes from a knowledge articulation perspective, which has been developed for this purpose (Oppl 2016b) and thus constitutes the second contribution of this thesis to this field.

Alignment with existing enterprise architectures refers to an area of research concerned with the (re-)integration of newly established or changed work practices in the socio-technical context of an organization. Altering organizational structures or processes usually requires to be reflected in supporting (IT-based) information systems and operational infrastructures. Implementing such changes consistently and in a timely manner is the major challenge of research in the field of enterprise architecting. The first contribution of this thesis to this field is a technical instrument that enables the automatic extraction of conceptual information from physically created model structures created in stakeholder workshops, which allows to seamlessly incorporate knowledge elicitation and alignment results in existing conceptual model repositories (Oppl et al. 2016). As a second contribution, models representing work processes can be transformed in a way that enables direct deployment to existing Workflow Management Systems for model validation or immediate operative work support (Oppl 2016a).

Methodologically, the research presented in this thesis follows a design science approach. The design theory on multi-perspective articulation and consolidation of knowledge about organizational work (Oppl 2016a) is the main artifact of the present work. Following the meta-requirements identified in the design theory, a collaborative conceptual modeling methodology has been proposed as an instantiated artifact of that design theory (Oppl & Alexopoulou 2016). In this context, a technical artifact has been developed to enable bridging the gap between the realm of social articulation and technical interpretation and deployment of models (Oppl et al. 2016). Several implementations of the methodology in the area of business process elicitation (Oppl & Alexopoulou 2016), organizational development (Oppl, 2016c) and information system design (Oppl 2016a) have been used to validate its adequacy with respect to the meta-requirements. Validation has required to engage in empirical method development (Oppl 2016b), as collaborative modeling processes so far had not been examined from a knowledge articulation perspective.

From a **practical perspective**, organizations benefit from the proposed approach as it supports operative staff to align conflicting understandings and resolve misconceptions about their work (Oppl 2016a; Oppl 2016d; Oppl & Alexopoulou 2016). This reduces the effects of unforeseen contingencies and allows to identify potential for improvement in the overall work process. As the work process usually is shaped and supported by information systems, these aligned views are reflected in conceptual models used to design these systems in order to appropriately support the work process.

1.1 Structure of this thesis

Chapters 3-7 of this habilitation thesis have been published as separate journal articles. They are included unaltered as regards content. They, however, have been modified in formatting and citation style to provide a consistent layout throughout this work. In addition, section and figure numbering has been altered to be consecutive across all articles to avoid misconceptions. The original articles are referenced in each chapter and are included in the annex to this work.

Chapter 2 has been written to provide the big picture of the research presented here. It puts the contributions of the included articles into the context of the global objectives and links them with each other. It discusses the theoretical contributions of the overall research effort from a design science perspective, puts into context the contributions of the following chapters and summarizes the achieved results from a global perspective. When describing the developed artifacts and reporting on the studies carried out for evaluation, it draws from the original articles contained in the remaining chapters of this thesis for reasons of consistency. It ends with outlining future directions of research on the overall topic of work articulation and alignment support.

Chapter 3 is an article originally published in Information & Management (Oppl 2016a). It presents the design theory on model-based articulation and alignment approach, which has been developed in the course of the research presented here. It describes the chain of instruments and presents an initial exploratory case study that shows the feasibility of the approach. It finally identifies the contribution the approach can provide in the process of information system design.

Chapter 4 is an article originally published in the International Journal of Information Systems Modeling and Design (Oppl & Alexopoulou 2016). It gives a more detailed account on the proposed collaborative articulation and alignment method than the article presented in chapter 3. The method is detailed on a conceptual level by adopting method engineering approaches and on a practical level by providing a more extensive and elaborate case study. It furthermore identifies the contribution the approach makes to the field of business process management, in particular during phases that focus on elicitation of domain-expert knowledge.

Chapter 5 is an article originally published in Information Systems and e-Business Management (Oppl 2016b). It examines the area of evaluation of collaborative modeling processes. It identifies an analytical gap of existing evaluation with respect to examining the epistemic dimension of collaborative articulation and negotiation during conceptual modeling. The presented evaluation approach is derived from the field of collaborative learning evaluation and is validated in a comparative case study, in which the outcome of current state-of-the-art approaches in collaborative modeling evaluation is compared with that of the proposed approach. This article provides the foundation of the empirical methodology deployed to examine the effects of the method introduced in chapters 3 and 4 on the development of a shared understanding about a collaborative work process.

Chapter 6 is an article originally published in Group Decision and Negotiation (Oppl 2016d). It presents empirical evidence that the method introduced in chapters 3 and 4 actually achieves its intended effects. It uses a multiple-case study design with a mixed-method approach for examining the behavior and experiences of participants of modeling sessions facilitated with the proposed approach.

Chapter 7 is an article originally published in the IEEE Transactions on Human-Machine-Systems (Oppl et al. 2016). It focusses on the technical gateway between the collaborative modeling components of the method proposed in chapters 3 and 4, which are based on placing cards on a shared physical modeling surface, and the validation components, which require a digital representation of the model for enacting it in a virtual execution environment. The system proposed in the article sets out to automate the process of transforming a card-based model to a digital representation by means of image recognition. It relaxes image capturing constraints imposed in the current state-of-the-art and allows workshop participants to take pictures of their models without any specialized infrastructure, e.g., by only using a smartphone.

Table 1.1 gives an overview about the design artifacts developed in each of the articles and outlines their contributions.

Table 1.1: Overview about developed artifacts

Article	Developed Artefact	Application Area	Contribution of Article to Thesis
Chapter 3 (Information & Management)	Methodology for articulation, alignment and elaboration	Enterprise Information System Design	Identification of design requirements, Methodological overview
Chapter 4 (Information Systems Modeling & Design)	Methodology for articulation, alignment and elaboration	Business Process Elicitation	Detailed method engineering
Chapter 5 (Information Systems & eBusiness Management)	Empirical method to examine knowledge construction in collaborative modeling processes	Collaborative Conceptual Modeling	Development of empirical method necessary for chapter 6
Chapter 6 (Group Decision & Negotiation)	Design theory on methodology for articulation and alignment	Process Knowledge Articulation and Alignment	Generalization of methodology, Empirical validation of methodology effects
Chapter 7 (Transactions on Human-Machine Systems)	Tool for extracting conceptual model information from physical card structures	Organizational Development	Development of enabling technology

Figure 1.1 visualizes the scopes and contributions of each article in relation to the elements of the design theory (process visualization adopted from (Oppl 2016a), cf. chapter 3).

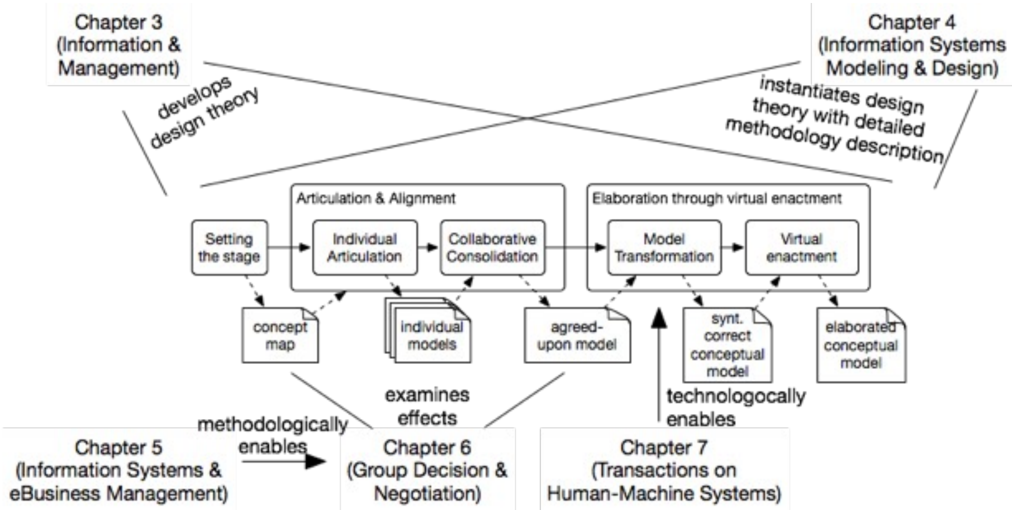

Figure 1.1: Scopes and contributions of included articles

2 CoMPArE — A Design Science Research Project[1]

2.1 Introduction

The research leading to the results presented in this thesis has followed a design science approach (Gregor & Hevner 2013). The articles presented in the following chapters give a detailed account on the developed artifacts, discuss their theoretical constituents and show their practical applicability in a number of case studies.

The overall picture of how the presented artifacts complement each other, which kernel theories have informed their design, and which methodological considerations have led to the implemented evaluation studies, however, can only be deduced implicitly from these single articles. The present chapter is dedicated to providing this global perspective.

The developed overarching design theory is referred to as CoMPArE in the following chapters. CoMPArE is an acronym for "*Co*nfrontative *M*ulti-*P*erspective *Ar*ticulation and *E*licitation" and represents the idea of facilitating the alignment of organizational behavior by confronting collaborating actors with the different perspectives they have on their work. This is done in a way that allows them to develop a shared understanding ("articulation") and generate representations thereof that can be processed by means of IT ("elicitation"). The rationale for pursuing this idea is briefly outlined in the following.

The deployment and use of IT-supported work support systems has gained rising importance since the 1980s for implementing organizational work processes (Curtis et al. 1992; Thome 1982). These systems do not solely aim at improving productive, value-adding work. They are also deployed as an instrument for governing and coordinating work to optimize the use of available resources (Orlikowski & Iacono 2001).

[1] This chapter gives an overview about the overall research reported on in this thesis, puts the contained articles (cf. chapter 3-7) into mutual context and discusses the global methodological approach and the underlying kernel theories. For reasons of consistency, it partially draws from the original articles. References to the sources are given in the respective section headings wherever necessary.

The focus on optimizing organizational resources for effective and efficient use is facilitated by conceptualizing organizational reality in enterprise architectures that describe the orchestration of resources to reach organizational goals (Jonkers et al. 2006). This abstraction is usually implemented by encoding and interlinking the social and technical elements of this architecture in conceptual models. These models can be processed by means of IT to provide support in process optimization as well as implementation (Curtis et al. 1992; Herrmann et al. 2002).

When enterprise architecture models are used as organizational artifacts to direct and control organizational work practices, the social and cognitive skills of the involved human actors are usually not explicitly considered (Davidson 2006). This can lead to suboptimal use of resources, as individual improvement of relevant skills might be ignored (Herrmann et al. 2002) and hampers adequate reactions on changing conditions in the organizational environment (Davidson 2006). Organizational behavior and functions of IT-based support measures gradually diverge, leading to a misfit between actors' expectations and actually provided support. This ultimately results in actors' ignorance of and resistance against IT-based support and guidance measures (Feldman & Pentland 2003).

Despite these challenges, socio-technical work support instruments such as ERP-systems (Enterprise Resource Planning), SOPs (Standard Operating Procedures), or MES (Manufacturing Execution Systems) are widely deployed in industry (Ragowsky & Somers 2002). Adoption has also risen in SMEs in the last decade (Haddara & Zach 2012), confronting virtually every organization directly or indirectly with guidance and support measures originating in these systems.

Operative actors in an organization thus have to cope with the potential discrepancy between the support measures provided based on idealized or outdated models of a work process and their perceived reality of their work situation (Davidson 2006). These perceived mismatches can range from inappropriately designed on-screen forms for data entry, over lacking information required for a specific work step, to work procedures that cannot be implemented in the way prescribed by a support system. They lead to workarounds, which increase the cognitive load and effort required by an organizational actor to complete the respective task, or to an accommodation of one's behavior to the routines and constraints encoded in the support systems (Davidson 2006; Soh et al. 2003).

Still, today's organizational work is shaped and influenced by requirements on standardization and documentation that can hardly be met without deploying socio-technical support systems (Botta-Genoulaz & Millet 2006; Davies et al. 2006). Active involvement of organizational actors in articulating and aligning their collaborative work processes thus has to be embedded in the context of the organizational reality shaped by these systems. Feldman & Pentland (2003) recognize this constraint and conceptualize it by distinguishing ostensive from performative aspects of work in an organization. They argue that, in order to influence the ostensive aspects of organizational work, the performative aspects have to be made visible in a form that is acceptable on all layers of an organization. While Feldman & Pentland (2003) do not detail this requirement any further, it shows that operative organizational actors — being the sources of performative aspects of work — have to be enabled to recognize and understand the ostensive mechanisms influencing their work (Weick et al. 2005), relate them to their performative behaviors (Davidson 2006), and articulate them in a form that allows them to directly influence the way their work is (ostensively) understood within the organization.

The skills necessary to create these commonly acceptable representations of work must not be taken for granted (Frederiks & van der Weide 2006; Recker & Rosemann 2009). Existing research addressing this issue considers organizational actors as mere sources of information, whose utterances about their work need to be transformed into a processable form by expert analysts (Herrmann & Nolte 2014; Hjalmarsson et al. 2015; Simões et al. 2016). This indirect approach, however, does not facilitate the alignment of different understandings about a work process (Türetken & Demirörs 2011) and might cause modelers' bias that manifests in incomplete or inappropriate representation of the work process (Goncalves et al. 2009). The alignment between the performative and ostensive aspects of organizational work thus is hampered and might lead to the introduction of further discrepancies between expected and actually provided work support measures.

The aim of the research presented in this thesis thus is to introduce support measures for articulating performative aspects of organizational work. These measures should allow organizational actors to articulate and align their views on their collaborative work processes, and still lead to a syntactically correct and semantically sound conceptual model for further processing in information systems.

The remainder of this chapter is organized along the structure proposed by Gregor & Hevner (2013) and Gregor & Jones (2007) to present design science research. It first presents the kernel theories informing the developed design theory and the developed artifacts. The deployed research methodology is then reviewed from a global perspective. Section 2.4 describes the developed artifacts and show how they relate with each other. Finally, the evaluation of the artifacts in different application domains in described in section 2.5.

This chapter does not fully summarize the results presented in the chapters 3-7. It rather provides them with a common background and puts them into mutual context. Consequently, the descriptions on the artifacts and their evaluations are kept brief and reference the details presented in the remainder of this thesis where appropriate. The content of this chapter in part has been adopted from the original articles contained in chapter 3-7. The sections containing or based on content published in other publications contain respective references in footnotes to the section headings.

2.2 Kernel Theories

The present research focusses on examining how human actors perceive, understand, articulate and align their collaborative work in an organizational context. Being a design science project, it ultimately aims at supporting this articulation and alignment processes by socio-technical means (Baxter & Sommerville 2011) to ultimately improve operative organizational work processes and work support systems. The theories informing the design of the artifacts to be developed consequently can be found in areas researching human interaction and collaboration in an organizational context. Figure 2.1 situates these theories in the MTO-framework („Mensch-Technik-Organisation“ — German for human — technology — organization) (Strohm & Ulich 1997) to show their respective foci.

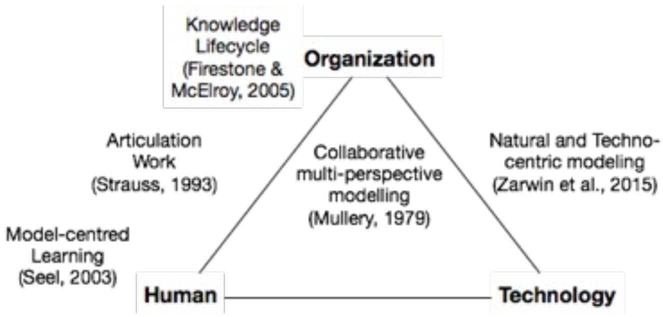

Figure 2.1: Kernel theories situated in the MTO-framework

Organizations are viewed as entities in which actors use their knowledge to perform business processes. If they are not able to satisfactorily complete their work, they deploy compensation activities and ultimately question the knowledge foundations they build their decisions on. In such a case, new knowledge is created in the organization that should allow to avoid the observed problems. The theory explaining and conceptualizing this process for the present work is the **Knowledge Lifecycle** of Firestone & McElroy (2003) (cf. section 2.2.1).

The knowledge lifecycle does not explicitly explain the activities of actors that lead to alignment of operative work in case contingencies arise. This issue is addressed by Strauss (1993) in his theory of **Articulation Work** (cf. section 2.2.2) that offers a descriptive framework of how workers overcome perceived obstacles in their collaborative work processes by implicit or explicit coordination activities (Strauss 1988). In the course of Articulation Work, the involved actors develop new knowledge that shapes their expectations of the behavior of their organizational environment in general and their collaborators in particular.

Neither the Knowledge Lifecycle, nor the concept of Articulation Work provide input on the mental processes of actors when developing new knowledge and how to support it. The theory of **model-centred learning** (Seel 2003), however, conceptually describes these mental processes and offers insights in how to facilitate them (cf. section

2.2.3). Enabling actors to explicitly articulate their mental models leads to their refinement (Ifenthaler et al. 2007), and creates results that can serve as boundary objects for making the mental models understandable for others (Dann 1992), ultimately making them accessible for alignment to create common ground on how to collaborate (Convertino et al. 2008).

The process of articulation and alignment of mental models can be supported by conceptual modeling practices (Recker & Dreiling 2011; Herrmann et al. 2002). In collaborative modeling, one challenge is to make sure that the views of all involved actors are considered in the final result. **Multi-perspective modeling** (Mullery 1979) addresses this issue by splitting the modeling process in a first phase, where the involved actors individually create models of their own perspective on the subject of modeling, and a second phase, where these models are consolidated in a structured way to form a single, agreed upon model (cf. section 2.2.4).

In order to support operative work processes, the results of articulation and alignment need to be made accessible for processing on an organizational and/or technical level. This poses requirements on the syntactical correctness of conceptual models that might not have been relevant during actor-centric modeling (Zarwin et al. 2014). The theory of the continuum between **natural and techno-centric modeling** (ibid.) enables to derive requirements on the artifacts to be developed in order to provide a link between articulation and alignment practices and integration of the results in existing enterprise architectures (Jonkers et al. 2004) (cf. section 2.2.5).

The following subsections summarize the mentioned kernel theories. At the end of each section, the respective theory is linked to its use in the present research.

2.2.1 Knowledge Lifecycle

The Knowledge Lifecycle (KLC) proposed by Firestone & McElroy (2003) is a process-oriented approach to knowledge management that builds upon different earlier approaches on organizational learning processes (mainly and foremost Argyris & Schön's (1978) concept of single- and double-loop-learning). The KLC introduces a fundamental distinction among activities performed in the "business processing environment" and activities performed in the "knowledge processing environment". Figure 2.2 provides an overview of the Knowledge Lifecycle as originally described by Firestone & McElroy (2003). Operative activities directly contributing to achieving a business goal are executed in the scope of the business processing environment. As long as the outcome of all activities and interactions is as expected, organizational actors (referred to as "interacting agents" in Figure 2.2) continue their activities in this mode. If problems occur, i.e., if some outcome does not comply with the expectations of any actor, learning occurs. Learning here always refers to a change in an organizational phenomenon referred to as the distributed organizational knowledge base (DOKB). The DOKB contains all knowledge an organization builds upon to pursue its aims, in both, uncodified or codified form, i.e., being anchored in the memory of actors or being explicitly implemented in specified business processes or IT systems.

The content of the DOKB is not altered without reason. If outcomes of particular activities match what has been expected based on knowledge from the DOKB, the beliefs about the correctness of the particular knowledge artifact are strengthened. If mismatches occur (i.e., if the outcome of an activity does not fit the expectations derived from the DOKB), learning occurs and affects the content of the DOKB. Learning conceptually is distinguished in single-loop- and double-loop-learning, following the approach of Argyris & Schön (1978). Single-loop-learning does not question the fundamental beliefs the activities that led to the mismatching outcome are based on. Rather, the way such activities are performed is adapted and populated back to the DOKB.

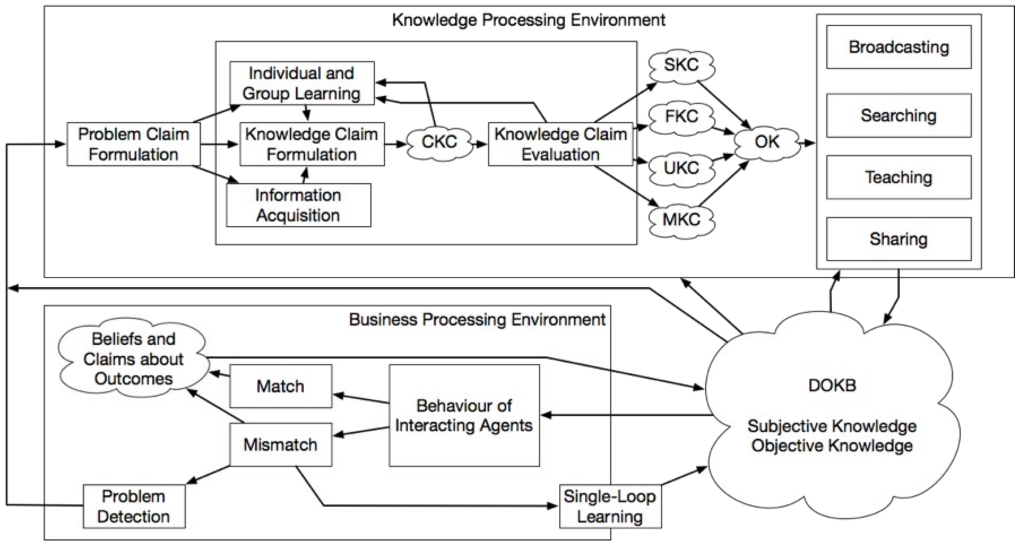

Figure 2.2: The Knowledge Lifecycle of Firestone & McElroy

If a more fundamental problem occurs and cannot be incorporated into the DOKB by assimilating a problem solution, the mismatch requires more fundamental consideration. Detection of such problems triggers a double-loop-learning process, which is executed in the knowledge processing environment (cf. Figure 2.2). Neither Firestone & McElroy (2003) nor Argyris & Schön (1978) specify the decision process that leads to either single-loop- or double-loop-learning in detail. The theory of model-centered learning provides an approach to describe this decision process from an individual perspective. The concept of Articulation Work allows bridging the conceptual gap between the KLC and model-centered learning and provides a starting point for developing support for this decision. Both theories are described below.

The knowledge processing environment is triggered with the formulation of a problem claim, i.e., a description of the problem that needs to be resolved. This problem claim is not necessarily yet agreed upon by all involved or affected actors — involvement of other actors mostly happens during knowledge production activities following later on. Based upon the problem claim, a knowledge claim is formulated. The knowledge claim contains the "new" knowledge (e.g., a fundamentally new version of a business process) and evolves over time in the iterative process of knowledge production. This process includes knowledge evaluation that takes an already codified (i.e., externalized) knowledge claim and verifies its correctness and applicability in the business processing environment based upon the current contents of the DOKB. As soon as no further revisions of the knowledge claim are considered necessary (Firestone & McElroy (2003) provide no statements on how to decide upon this – again, Articulation Work can be used as a starting point here), knowledge distribution is triggered. Knowledge distribution takes the outcome of the knowledge production activities (which can also be falsified or undecided knowledge claims, i.e., knowledge claims that did not solve the problem that occurred in the business processing environment) and makes it accessible to the organization as a whole. The means of distribution are manifold, with the common objective of integrating the new knowledge in the DOKB. Activities here can range from distributing the codified knowledge claim to the relevant actors and stakeholders in the organization to implement it in an IT-system that prescribes new behavior in the business processing environment. The knowledge lifecycle is closed via the re-integration of the outcomes of the knowledge processing activities into the DOKB. New knowledge persisted in the DOKB eventually can be used for future activities in the business processing environment.

The knowledge lifecycle is explicitly used as a framework for discussing the interplay of the artifacts developed in the present research in chapter 2 and (Oppl et al. 2016) (cf. chapter 7).

2.2.2 Articulation Work

The knowledge lifecycle does not explicitly address how work is organized by interacting agents in the business processing environment and how they react upon observed contingencies. Work is an inherently cooperative phenomenon (Helmberger & Hoos 1962). Whenever people work, they have interfaces to others, either cooperating directly to perform a task or mediated via artifacts of work, which they share (Strauss 1985).

Cooperative work requires that participating parties have a common understanding of the nature of their cooperation. This includes dimensions such as when, how, and with whom to cooperate using certain means. The mutual understanding of cooperation has to be developed when cooperative work starts and has to be maintained over time, as changing environment factors may influence cooperation (Fujimura 1987). All activities concerned with setting up and maintaining cooperative work are summarized using the term "Articulation Work" (Strauss 1985). Articulation Work mostly happens implicitly and is triggered during the actual productive work activities whenever contingencies arise (Gerson & Star 1986). Cooperative practices are established without a conscious act of negotiation in "implicit" Articulation Work, relying on social norms and observation to form a mutually accepted form of working together (Strauss 1988).

Implicit Articulation Work, however, is not sufficient when cooperative work situations are perceived to be "problematic" or "complex" by at least one of the involved parties (Strauss 1993). The terms "problematic" and "complex" here explicitly refer to individual perceptions, and are intrinsically subjective. As such, they cannot be detailed from an outsider's perspective. Consequently, relying on implicit articulation work can influence cooperation substantially. Different understandings of the same work situation impact the way of accomplishing tasks and the quality of work results, as long as articulation work remains on an implicit level.

Negotiation and development of a common understanding has to be carried out deliberately and consciously in such cases. This has been termed "explicit" Articulation Work by Strauss (1988). The expected outcome is to enable involved stakeholders starting or continuing their cooperative work towards a shared goal. The roles and activities of stakeholders involved in explicit Articulation Work need to be clarified, as it goes beyond implicit Articulation Work and prevention of "problematic" (as termed by Strauss) situations.

Conducting Articulation Work facilitates the alignment of individual views about collaborative work. Strauss (1993) argues, that these individual views (termed as "thought processes" and "mental activities") affect human work and direct individual action. In particular, for problematic or complex work situations, where social means of alignment (Wenger 2000) might not be sufficient, a closer look at the individuals' understandings of their and others' work is of interest. It should enable to design effective support measures for explicit articulation work. From how "thought processes" are described by Strauss (1993), they correspond to instances of "schemes" and "mental models" in cognitive sciences (Johnson-Laird 1981). The modification of mental models in the course of articulation work thus can be described using the theory of model-centered learning (Seel 2003).

The term “articulation” used in the present research refers to the concept established by Strauss (1993). The two articles in this thesis establishing the theoretical foundations of the developed methodological artifact ((Oppl 2016a), cf. chapter 3, and (Oppl 2016d), cf. chapter 6) explicitly reference the theory of Articulation Work in their introductory sections.

2.2.3 Model-centered learning[2]

People’s activities in a work process, their decisions and reactions to contingencies are driven by their perception of organizational reality (Weick et al. 2005). How people perceive their work context in an organization and how they derive their reactions on

[2] Partially taken and adapted from (Oppl 2016e).

these perceptions is examined in cognitive sciences in the field of mental model theory (Johnson-Laird 1981). Mental model theory also has been used in knowledge management to explain operative triggers of organizational change processes (Firestone & McElroy 2003). Mental model theory here is used to describe individual and collective learning processes, i.e., the adaptation of mental models to accommodate perceived changes in the organizational environment (Seel 2003).

Mental models are cognitive constructs that are used by persons to make plausible and assess their perceptions of phenomena in the real world (Seel 1991). Consequently, the alignment of individuals' views on work manifests in changes of the individuals' mental models — these changes are considered a form of learning (Seel 1991). The concept of "model-centered learning" (Seel 2003) thus provides the foundation to design support instruments for explicit Articulation Work.

Model-centered learning is based on the constructs "scheme" and "mental model" (cf. Figure 2.3). They serve to explain different strategies of humans to cope with external stimuli. Schemes are generalized abstract knowledge patterns that are derived from prior experiences. They are used to immediately react on phenomena in the perceived reality without further planning activities. In situations that differ from prior experiences or are completely new to an individual, schemes are not applicable. Individuals create mental models in these cases to explain their perceptions and derive adequate reactions. Mental models might be incomplete or even be inherently contradictory. Individuals develop mental models for one particular situation only to a point enabling them to react on the stimulus in a way they consider adequate.

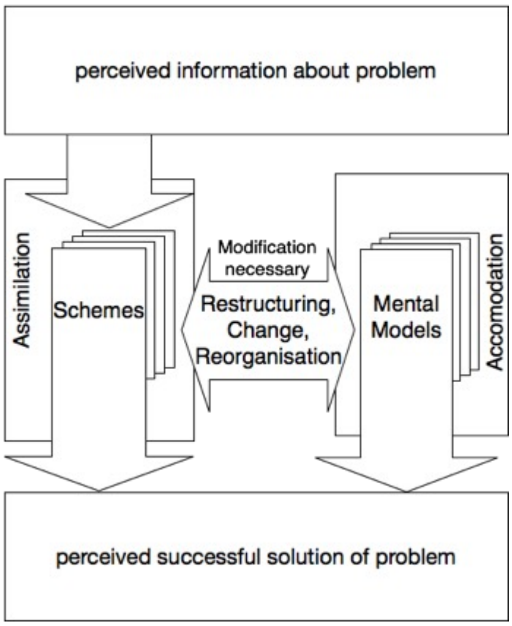

Figure 2.3: Schemes and Mental Models (translated and adapted from (Ifenthaler 2006))

Mental models become more elaborate as more and more external stimuli and perceived information about the environment are incorporated. This process of “accommodation” of mental models is considered a form of learning (Seel 1991). In the course of learning, mental models evolve from “novice models” over “explanatory models” to “expert models” (or “scientific models”), where the amount of information about causal relationships about phenomena in the real world increases from the former to the latter (Ifenthaler 2006). It is, however, important to note that expert models are not considered the desired aim of learning in any case. Due to the complexity of expert models, ad-hoc decisions based on perceived situations become more difficult and the perceived "usefulness" of the mental models degrades (Ifenthaler 2006). In most cases, explanatory models are perceived as “most useful”, as they contain all information necessary to correctly judge a given situation (Ifenthaler 2006).

Depending on the situation, explanatory models may be rather simple or complex and contain less or more information, making them either more similar to a novice or an expert model. In terms of Articulation Work, expert models are hardly ever necessary, as they would require the individual to fully comprehend the entire work situation including the contributions and rationales of all other participants. In most situations, it is sufficient to develop an explanatory model of one's role in the overall work process and the interfaces to immediate co-workers. Elaborate explanatory models reduce the perceived complexity of work situations and thus enable focusing on the actual productive cooperative work.

Mental models evolve through experience in real world situations. Whenever an individual is confronted with perceptions that cannot be assimilated by existing schemes or be explained by current mental models, these models evolve and accommodate to the new perceptions (cf. Figure 2.3). The goal of accommodation is to enable adequate action in situations similar to the one just perceived.

Mental model change requires to recognize the lack of adequacy of one’s mental model and the opportunity and willingness to reflect on and adapt the mental model. In collaborative work settings, mental model change might not be restricted to a single person but might require to involve all actors in the work process in the reflection and change process. The willingness of changing a mental model that has been recognized to be inadequate by an individual can be assumed (Weick et al. 2005) (not imposing any assumptions about the quality of the change). Still, having the opportunity to adapt a mental model by gathering the required input and being able to retrieve it in an adequate form, can be an issue (ibid.). Furthermore, in collaborative settings, the willingness of other actors to change their mental models must not be assumed. If they do not perceive the environmental setting to be „problematic“ (Strauss 1988), inquiries for change are usually met with resistance (Ifenthaler et al. 2007).

Those challenges of can be met with explicit activities dedicated to articulation, reflection and alignment of individual mental models (Seel et al. 2009). Such activities need to be facilitated by providing artifacts that can serve as focal points of discussion and act as anchors for developing a mutual understanding about the subject at hand (Dix & Gongora 2011). Conceptual models have been widely recognized as an appropriate mean to serve as external artifacts representing mental models (Novak 1995; Pirnay-Dummer & Lachner 2008; Chabeli 2010).

The theory of model-centered learning is explicitly referred to in the two articles in this thesis establishing the theoretical foundations of the developed methodological artifact ((Oppl 2016a), cf. chapter 3, and (Oppl 2016d), cf. chapter 6) in their introductory Sections when motivating the added value externalized representations of work processes can be provided when aiming to develop a shared understanding.

2.2.4 Collaborative multi-perspective modelling[3]

Using collaborative conceptual modeling activities for creating a shared understanding about organizational phenomena has already been discussed extensively in prior research. Recently, research in the area of conceptual modeling has recognized that the added value of collaborative modeling not only is generated via the resulting models, but also by creating common ground about the modeled process for the involved people (Hoppenbrouwers et al. 2005). Research has started to examine how these modeling processes can be facilitated to support the evolution of common ground (Hoppenbrouwers & Rouwette 2012). In this line of research, several efforts have been made to qualitatively describe the effects occurring in such modeling sessions (Rittgen 2007; Seeber et al. 2012). The modeling process is considered to be a series of negotiation acts, with the model being an artifact generated as an outcome. Support measures in the process of modeling consequently focus on enabling and documenting negotiation acts. The process of process modeling has also been examined from a cognitive perspective, focusing on the development of understanding on the subject of modeling for the individual modeler (Soffer et al. 2012), where the authors discuss the cognitive fit of available modeling constructs as a factor influencing the process of modeling.

In the area of conceptual modeling of work processes, the idea of enabling multiple actors to explicitly articulate their individual understanding of their work contribution in separate models and use them as the foundation for consolidation in a structured way has first been proposed by Mullery (1979). The multi-perspective modeling paradigm focuses on the representation of individual work contributions in models and subsequently merges them into a common model by agreeing on the interfaces among the

[3] Partially taken and adapted from (Oppl 2016d). The full article is included in chapter 6.

individual models. It explicitly specifies the model elements which are subject to alignment, distinguishing them from the model parts that remain the responsibility of the individual actors.

This approach has been picked up by Türetken & Demirörs (2011), who propose a decentralized process elicitation approach ("Plural") in which individuals describe their own work. It uses eEPC (Nüttgens & Rump 2002) as a modeling language. Plural uses tool support built upon a commercial modeling environment, which identifies inconsistencies between individual models. Front et al. (2015) adopt multi-perspective modeling in the ISEA approach ("Identification, Simulation, Evaluation, Amelioration"). Perspectives here not exclusively refer to individual work contributions, but are understood as putting different aspects of an organization into the focus of observation (e.g., information, organization, interaction). Modeling is tightly integrated with means of simulation, which allows to evaluate the perceived correctness of the models and alter them accordingly.

Collaborative modeling and negotiation are also promoted by the COMA approach (Rittgen 2009b), which focuses on providing support for articulating and consolidating models during collaborative modeling with a language-agnostic negotiation approach. The COMA tool enables actors to communicate via the software in a structured way specified by the COMA methodology. Following its negotiation-oriented approach, COMA provides guidance for model consolidation (i.e., the negotiation process), which thus makes explicit divergent views and suggestions for a common view, which is ultimately agreed upon with the support of a human facilitator.

The usefulness of multi-perspective modeling as proposed by Mullery (1979) has also been backed by results for cognitive sciences in the field of collaborative learning (Engelmann & Hesse 2010) and mutually revealing and understanding mental models (Groeben & Scheele 2000). Engelmann & Hesse (2010) show that sharing of individually created concept maps about a topic improves mutual understanding within a group and improves the group members' performance in terms of problem solving skills related to this topic. Groeben & Scheele (2000) propose to adopt a dialogical approach to create a shared understanding about mental models. They use a tailored conceptual modeling language to explicitly represent these mental models and make them a subject of dialogue that ultimately reflects the reached consensus.

Dean et al. (2000) have examined the effects of different group modeling approaches, and found that having participants work on separate parts of a single model increases individual involvement but leads to inconsistencies that need to be resolved in a separate step. These inconsistencies can be partially prevented when using a modeling approach that is guided by a human facilitator. Similar results have been observed by Hjalmarsson et al. (2015), who conducted empirical research in the area of facilitation of business process modeling workshops. They were able to identify different facilitation styles that are characterized by different behavioral patterns of the facilitator. The appropriateness of these styles is dependent on situational factors of the modeling setting and prior modeling knowledge of the participants.

The theory of collaborative multi-perspective modeling is the fundamental design principle deployed in the development of the main methodological artifact introduced in the present research. It is used as the foundation for method design in (Oppl 2016a) (cf. chapter 3) and (Oppl & Alexopoulou 2016) (cf. chapter 4) and is operationalized in the design theory introduced in (Oppl 2016d) (cf. chapter 6).

2.2.5 Natural and Techno-centric modeling[4]

Actively involving process participants in process modeling creates several challenges: Process participants cannot be expected to have modeling skills, and usually, as stated by Prilla & Nolte (2012), they are not necessarily willing to learn a modeling language with a strict syntax and semantics and many different symbols. What they would prefer would be to externalize their knowledge through diagrams that are as simple as possible in terms of both syntax and semantics. Zarwin et al. (2014) also discuss these issues and stress the importance of what they refer to as *natural modeling*. With this term, they aim at shifting the focus of attention from the technical and formal aspects of modeling to human aspects, since modeling has always been a human-intense activity. For modeling to be widely accepted, Zarwin et al., claim that it should be as natural as possible. To this end, they specified three principles: 1) modeling should be based on intuitive symbols and constructs, 2) modeling should be collaborative, so that models can serve as vehicles of communication facilitating knowledge sharing and promoting negotiation and commonly agreed-upon decisions, and 3) modeling should be flexible in a sense that the symbols do not have a predefined meaning but rather the language used should emerge dynamically based on the situation at hand. They, however, also claim, that – if the ultimate goal of the models produced is their technical processing – modeling support needs enable modelers to work in a continuum between "natural and formal modelling", which "should be fundamentally understood as the two polarities" (Zarwin et al. 2014) (p. 29).

Much existing research on collaborative modeling targets inexperienced modelers and natural modeling practices. Research on facilitating lay modeling focuses on measures to guide inexperienced modelers through the process of creating a model without overwhelming them with syntactic formalism and complex modeling constructs. Existing research (e.g., (Santoro et al. 2010; Fahland & Weidlich 2010; Kabicher &

[4] Partially taken and adapted from (Oppl & Alexopoulou 2016). The full article is included in chapter 4.

Rinderle-Ma 2011; Lai et al. 2014)) suggests that starting modeling based upon a concrete work case makes it easier for inexperienced modelers to develop an understanding of the necessary concepts to describe a work process in an abstract conceptual model.

Using a case-based approach to modeling also reduces the number of language elements necessary to depict the work process. For example, case-based models do not require decision constructs or elements for exception handling. While the number of modeling elements alone appears not to have a notable impact on the understanding of a modeling language for inexperienced modelers (Recker & Dreiling 2007), empirical evidence shows that the number of elements actually used during modeling is limited and highly dependent on the modeling objective (Muehlen & Recker 2008). When involving inexperienced modelers, it seems to be appropriate to limit the number of available modeling elements a priori to those appropriate for the intended modeling perspective and targeted outcome (Genon et al. 2011; Britton & S. Jones 1999).

Furthermore, Herrmann & Nolte (2014) and Santoro et al. (2010) provide evidence that non-formalized information and annotations to model elements can aid the externalization process, as this does not force the modelers to express all information using the constructs of the modeling language. Some results also point at the importance of (human or automatic) facilitation and scaffolding during the model creation process (Hjalmarsson et al. 2015) and the model alignment process (Rittgen 2007), particularly for inexperienced modelers (Davies et al. 2006). Current research indicates that procedural and structural scaffolds provided by a facilitator or an automated system may support the elaboration of incomplete models (Herrmann & Loser 2013; Hoppenbrouwers et al. 2013; Oppl 2016e; Oppl & Hoppenbrouwers 2016).

The topic of supporting and guiding inexperienced modelers to make use of natural modeling practices for articulation and alignment and subsequently develop more formalized, techno-centric models is addressed in (Oppl 2016a) and (Oppl & Alexopoulou 2016) by elaborating the articulated models via virtual enactment and in-situ refinement. This practice is technologically enabled with the artifact introduced in (Oppl et al. 2016).

2.2.6 Integration

The presented kernel theories have been used as the foundation for artifact development as discussed in the introduction to this section. The MTO-framework (Strohm & Ulich 1997) can be used again to visualize the different foci of research addressed in this thesis (cf. Figure 2.4).

The main focus of the design science project is to facilitate human actors' articulation and alignment of their views on collaborative organizational work practices. Socio-technical artifacts are developed to enable this facilitation. The thesis furthermore examines, how the deployment of the developed artifacts changes the involved actor's perception of their work in an organizational context and how they progress to develop a shared understanding about their collaborative work. The articulation results are represented in a form that enables to influence existing enterprise architectures on both, an organizational and technical level, making use of concepts developed in the fields of business process management and information system design.

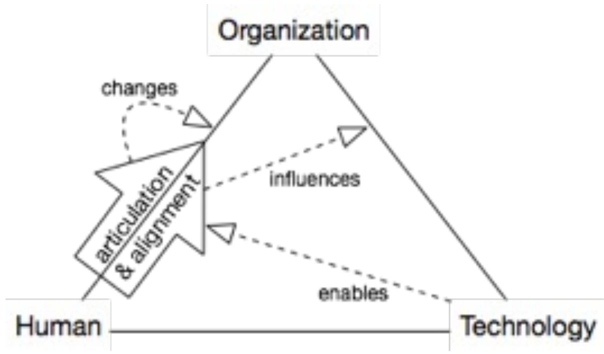

Figure 2.4: Foci of research addressed in this thesis

Figure 2.5 maps these foci of research to the chapters of this thesis, which contain the original articles reporting on the developed artifacts and evaluations carried in the different addressed fields.

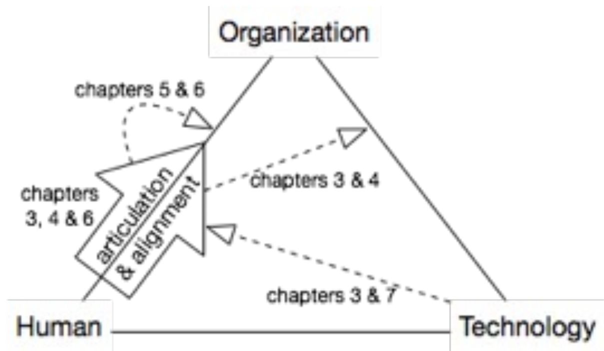

Figure 2.5: Foci of research addressed in the chapters of this thesis

2.3 Research methodology

The present research follows a design science process (Peffers et al. 2007). Methodologically, it adopts a problem-centered initiation approach (ibid.), i.e., it draws its motivation from existing problems identified in literature and offers novel solutions for these problems. It thus can be considered an „improvement“ (Gregor & Hevner 2013) to the existing state-of-the-art in stakeholder-centric articulation and alignment of work process knowledge.

Following the Information Systems Research Framework proposed by Hevner et al. (2004), the **relevance** of the developed theories and artifacts is justified from a people-oriented perspective in terms of improving organizational actors' capabilities in modeling and their understanding of their work (as demonstrated in (Oppl 2016d)), from an organization-oriented perspective in terms of improving organizational alignment of collaborative work processes (as demonstrated in (Oppl & Alexopoulou 2016)), and from a technology-oriented perspective in terms of an improvement of elicitation processes for information systems design and development (as demonstrated in (Oppl 2016a)).

The knowledge base the present work draws from have been outlined in the former section. **Rigor** is ensured by adopting existing theories and frameworks in the fields of articulation support in collaborative settings and conceptual modeling support for inexperienced modelers. Evaluation is based on established empirical methodologies in the area of collaborative co-construction of a shared understanding (Weinberger & F. Fischer 2006) and is implemented following a case study research design (Yin 2009) that allows to assess the effects of the developed artifacts in real-world applications. The present research adds to the knowledge base of the relevant fields by contributing to the development of a theory on articulation support in collaborative work settings (as shown in (Oppl 2016a; Oppl 2016d)), providing concrete methods for this purpose (as shown in (Oppl & Alexopoulou 2016)) and tools that support their implementation (as shown in (Oppl 2016a; Oppl et al. 2016)), and proposing a data analysis technique that allows to assess the process of developing a shared understanding in collaborative conceptual modeling processes (as shown in (Oppl 2016b)).

Artifact design and development in general has followed the process described by Peffers et al. (2007). The design of the main artifact supporting articulation and alignment has been motivated from the observed lack of support for actor-driven design of work processes and work support systems as described above. In the course of development iterations, the methodological artifact was generalized towards a design theory for articulation and alignment of performative aspects of organizational work in general, which manifest in generic meta-design requirements and a design pattern for methodological support of such processes. Furthermore, in order to appropriately support the implementation of the developed methodology, two technical artifacts have been developed, motivated by the need in reducing effort and cognitive load for organizational actors in developing their articulated models towards representations that can be used to shape the ostensive aspects of organizational work.

The development of the methodological artifact and the supporting technological artifacts has been performed iteratively with frequent practical testing and demonstrations for information system design problems (Oppl 2016a) and business process elicitation (Oppl & Alexopoulou 2016). In an effort to evaluate the effectiveness of the proposed methodological artifact, a suitable evaluation method for assessing knowledge articulation and alignment in collaborative modeling session has been developed (Oppl 2016b) and deployed in a multiple-case-study (Oppl 2016d). The findings of this study have been used to elaborate on the proposed design theory (started in (Oppl 2016d) and continued in (Oppl 2016c)). The developed technical artifact for enabling seamless transition between articulation- and alignment-oriented modeling to IT-supported modeling and execution environments has demonstrated its effectiveness in a quasi-experimental study and was evaluated in another case study in the field of organizational development (Oppl et al. 2016). The technical artifact enabling the validation and elaboration of articulated models through virtual enactment has demonstrated its usefulness in two showcases (Oppl 2016a; Oppl & Alexopoulou 2016), but has not yet been extensively evaluated regarding its effectiveness. This is subject of currently ongoing research.

The research reported on here has not been started from scratch. Earlier artifacts similarly pursuing the aim of articulation and alignment of mental models about work using interactive tangible tabletop interfaces are described in (Oppl 2011), (Oppl 2013) and (Oppl & Stary 2014).

2.4 A design theory on knowledge articulation through collaborative modeling[5]

In the following, *CoMPArE* is introduced as a design theory for collaborative articulation and alignment of individual understandings about collaborative work processes. CoMPArE is situated in the knowledge lifecycle (Firestone & McElroy 2003) in the transition from the business processing environment to the knowledge processing environment and is usually deployed for problem claim identification and formulation as well as the creation and evaluation of new knowledge about work. It is embedded in an overall chain of instruments that has been developed over the last years to enable work-process-oriented support for instantiating the knowledge lifecycle[6]. Figure 2.6 gives an overview about the role of CoMPArE in this set of instruments.

Our research has focused on support for activities in the knowledge processing environment in the KLC so far, with tools supporting the collaborative development of a shared understanding about a work context (Oppl & Stary 2014), negotiation processes for setting up or revising work procedures (Oppl 2015), validation of proposed work processes (Schiffner et al. 2014), as well as sharing (Neubauer et al. 2013) and

[5] Partially taken and adapted from (Oppl 2016a), (Oppl 2016d), and (Oppl et al. 2016). The full articles are included in chapters 3, 6, and 7. Parts of the discussion of the instantiation process are translated from (Oppl 2016c).

[6] These efforts have mainly been subject of the FP7 IAPP project IANES (http://www.ianes.eu), lead by the author of this thesis as a coordinator and principal investigator.

contextualizing (Fürlinger et al. 2004) the developed artifacts in an organization. All of them support the operationalization of the knowledge processing environment depicted in the upper part of Figure 2.6. Further instruments have been developed to support compensation activities for mismatches occurring in the business processing environment depicted in the lower part of Figure 2.6 (Schiffner et al. 2014; Kannengiesser & Oppl 2015). The remaining gap is to identify problem claims in a work situation and formulating the problem claims. Bridging this gap would enable organizational actors to articulate their views on the occurred mismatches. It could facilitate the transition from the business processing environment to the knowledge processing environment and allow starting knowledge production by providing context from the actual work situation.

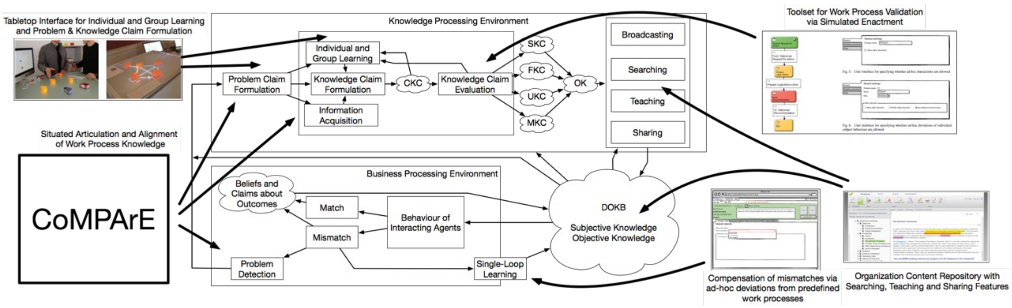

Figure 2.6: Role of CoMPArE in the knowledge lifecycle

The instruments developed for supporting the knowledge processing environment (Oppl & Stary 2009; Wachholder & Oppl 2012) have been shown to fulfill their design goals (Oppl & Stary 2014), but require dedicated technical infrastructure. This prevents their deployment in operative work settings as well as operation without support staff trained to solve technical issues. The aim of CoMPArE thus is to methodologically and technically enable a transition from the perceived problem situations in the business processing environment, over articulating problem claims to the formulation and evaluation of new knowledge through alignment and validation activities focusing on developing and documenting a shared understanding about future collaborative work processes.

2.4.1 Meta-Requirements

Based on the discussion of the kernel theories in the last section, four major meta-requirements (Walls et al. 1992) can be identified that need to be adhered to in order to facilitate articulation and alignment:

2.4.1.1 Articulation Requirement 1

In order to be able to identify different perceptions of how collaborative work is carried out, the individual mental models of the collaborating contributors need to be made accessible for alignment (Engelmann & Hesse 2010; Novak & Canas 2006). Externalization of mental models (i.e., creating explicit representations of mental models) is a recognized means to serve this purpose. Conceptual models are a form of representation that has been shown to be suitable for mental model externalization (Ifenthaler et al. 2007). The act of representation leads to elaboration of the mental model of the externalizing individual, creating a result that serves as an artifact for making the mental model understandable for others (Dann 1992; Rittgen 2007; Türetken & Demirörs 2011). Consequently, a collaborative modeling approach to work should profit from a phase during which the participants individually externalize their mental model of the work process in the form of a conceptual model (*AR 1*).

2.4.1.2 Articulation Requirement 2

A common vocabulary used by all involved participants to describe their mental models is a prerequisite for alignment on content level (Sarini & Simone 2002; Roschelle 1996). The existence of common ground here cannot be taken for granted, particularly when people with a diverse professional background are involved (Sarini & Simone 2002). The relationship between the vocabulary used to describe concepts in the real world and the actual real world phenomena is not unique, since different notions can be used by different people to refer to the same concept (Roschelle 1996; Weinberger et al. 2007). Explicitly aligning the notions used to describe the aspects of a work process in a model therefore contributes to creating common ground (F. Fischer & Mandl 2005) (*AR 2*).

2.4.1.3 Articulation Requirement 3

Furthermore, the scope of the work process might not be obvious for all participants or even might be perceived differently by the participants (Weinberger et al. 2007). Facilitating a convergence of the understandings of the scope of the work (e.g., what triggers the start of the work process and how its end is recognized) and how the work environment is set up (e.g., identifying the relevant actors, necessary infrastructure, utilized resources, location of the process and/or its parts, etc.) is necessary before externalizing the individual contributions to the work model (*AR 3*).

The modeling approach to be developed here thus should facilitate the following activities: (1) creating individual models of the work process before creating a common model, (2) agreeing on a common description of the work process elements, and (3) creating common ground about the scope of the work process.

2.4.1.4 Articulation Requirement 4

The results of these activities provide a foundation for reaching common ground about the work process. This can be facilitated by conceptual models that serve as a shared artifact (F. Fischer & Mandl 2005). Weinberger et al. (2007) show that common ground develops through argumentative alignment of individual claims made by the participating actors. A conceptual modeling approach supporting this process should allow for the expression of individual claims and place them in the context of other claims for reviewability in the argumentative chain. This allows conflicting claims to be expressed and monitored, which is important since they need to be resolved in order to ultimately create a commonly agreed upon model (*AR 4*).

Approaches toward collaborative work modeling have already been discussed in the introduction. This prior research has identified additional supportive factors that have to be taken into account when designing a collaborative modeling method to support articulation and alignment. These modeling support factors (MSF) are described in the following.

2.4.1.5 Modeling Support Factor 1

Much existing research on collaborative modeling targets inexperienced modelers. Requirements originating from this target group are relevant for the present research, as operative work staff cannot be expected to have modeling experiences. Research on facilitating lay modeling focuses on measures to guide inexperienced modelers through the process of creating a model without overwhelming them with syntactic formalism and complex modeling constructs. Existing research (e.g., (Santoro et al. 2010; Fahland & Weidlich 2010; Kabicher & Rinderle-Ma 2011; Lai et al. 2014)) suggests that starting modeling based upon a concrete work case makes it easier for inexperienced modelers to develop an understanding of the necessary concepts to describe a work process in an abstract conceptual model (*MSF 1*).

2.4.1.6 Modeling Support Factor 2

Using a case-based approach to modeling also reduces the number of language elements necessary to depict the work process. For example, case-based models do not require decision constructs or elements for exception handling. While the number of modeling elements alone appears not to have a notable impact on the understanding of a modeling language for inexperienced modelers (Recker & Dreiling 2007), empirical evidence shows that the number of elements actually used during modeling is limited and highly dependent on the modeling objective (Muehlen & Recker 2008). When involving inexperienced modelers, it seems to be appropriate to limit the number of available modeling elements a priori to those appropriate for the intended modeling perspective and targeted outcome (Genon et al. 2011; Britton & S. Jones 1999) (*MSF 2*). In the present case, the modeling perspective is oriented towards the work of actors and their interactions within an organization. The targeted outcome is reaching common ground on the work process for non-expert modelers.

2.4.1.7 Modeling Support Factors 3 and 4

Furthermore, Herrmann & Nolte (2014) and Santoro et al. (2010) provide evidence that non-formalized information and annotations to model elements can aid the externalization process. However, they do not force the modelers to express all information using the constructs of the modeling language (*MSF 3*). Some results also point at the importance of (human or automatic) facilitation and scaffolding during the model creation process (Hjalmarsson et al. 2015) and the model alignment process (Rittgen 2007), particularly for inexperienced modelers (Davies et al. 2006) (*MSF 4*). Current research indicates that procedural and structural scaffolds provided by a facilitator or an automated system may support the elaboration of incomplete models (Herrmann & Loser 2013; Hoppenbrouwers et al. 2013). The effectiveness of these approaches, however, still needs to be validated empirically.

2.4.1.8 Summary

Summarizing, the following meta-requirements on a modeling approach support collaborative modeling by inexperienced modelers: (1) starting with case-based development of process models, (2) offering a constrained set of modeling constructs with semantics focused on the modeling objective, (3) enabling informal annotations of model elements (i.e. not adhering to formal modeling syntax), and (4) offering procedural and structural scaffolds for model creation and alignment.

Figure 2.7 shows the articulation requirements (ARs) and modeling support factors (MSFs) derived above. Implementing ARs 1 and 2 is at the core of supporting the transition from potentially divergent individual mental models about work to a commonly agreed-upon externalized representation of a work process that provides a sound foundation for the development of a shared understanding. ARs 3 and 4 support this transition by clarifying the scope of work and keeping track of the articulation and alignment process, respectively. The implementation of the ARs by means of conceptual modeling is facilitated if MSFs 1-4 are considered during method design. MSFs 1 and 2 are relevant in particular for implementing AR 3, whereas MSFs 3 and 4 enable the implementation of AR 4. All four MSFs are finally relevant for ARs 1 and 2.

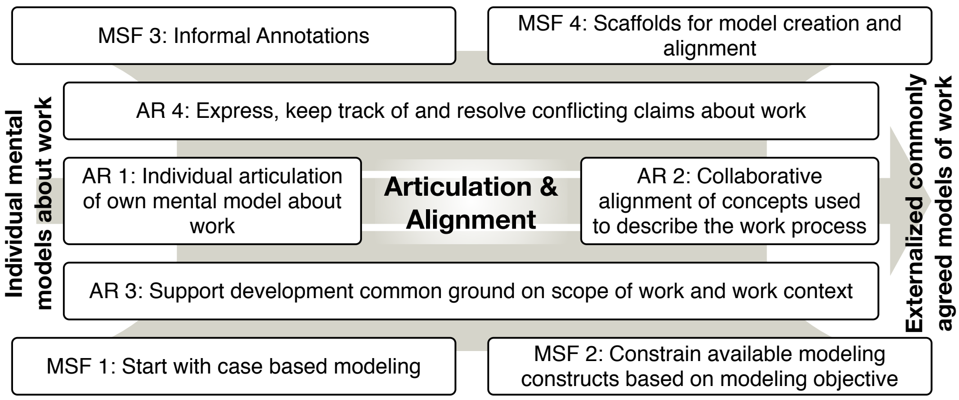

Figure 2.7: Meta-requirements to be addressed in instantiations of CoMPArE

2.4.2 Design Pattern

The meta-requirements are encoded in a design theory, which here takes the form of a pattern for methodology design (Walls et al. 1992). CoMPArE facilitates collaborative articulation of work processes using conceptual modeling techniques. Collaborative conceptual modeling is a recognized means to facilitate the development of a common understanding between people about a subject of discourse (Herrmann et al. 2004). The conceptual models serve as externalized artifacts representing the participants' mental models and so act as mediators for the development of a shared understanding (Groeben & Scheele 2000).

The necessary properties identified in the former section are addressed in CoMPArE by offering patterns to design structural and procedural guidance in a three-step modeling approach (cf. Figure 2.8).

The first step focuses on collaboratively developing a common vocabulary to refer to the relevant real-world phenomena in the following steps (*AR 2*). It furthermore helps to agree on the scope of modeling and in this way clarify about the aspects of organizational work to be agreed upon.

The second step makes sure that every involved participant is able to contribute his or her individual view on the work process (*AR 1*). The third step aims the development of a shared understanding (*AR 3*) and needs to avoid the unreflected acceptance of inconsistent or conflicting views by explicitly confronting the participants with these issues (*AR 4*). Figure 2.8 shows a generic scheme for this process. The steps are described in the following in more detail.

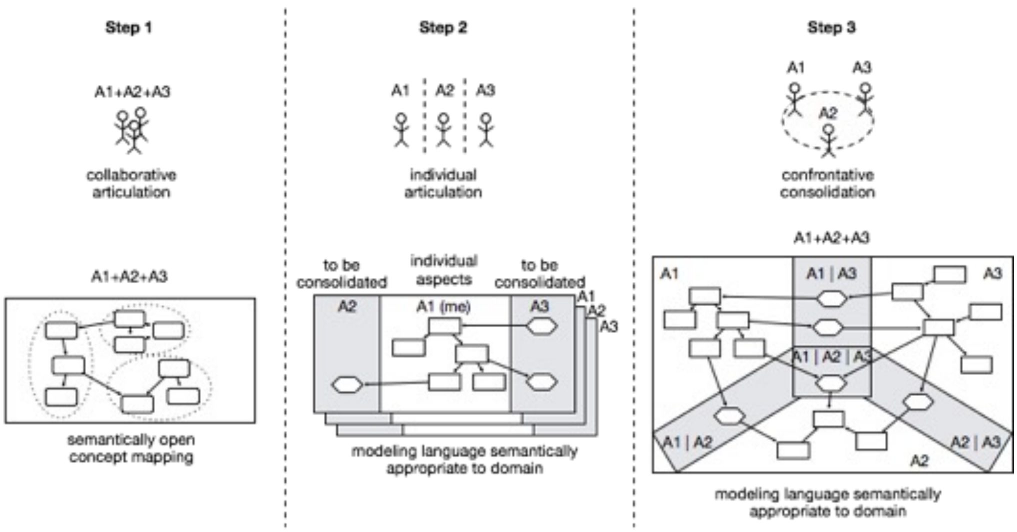

Figure 2.8: Generic articulation and alignment steps in CoMPArE

The modeling support mechanisms aiming at facilitating alignment activities need to be integrated in the modeling approach (*MSF 4*). This, however, cannot be done generically for all potential modeling languages. Work processes in organizations can be described with different foci (Curtis et al. 1992) that require conceptual modeling languages to provide different language constructs to describe appropriately the respective aspect (Krogstie et al. 1995). The used modeling language thus needs to be tailored to the targeted aspect of articulation (*MSF 2*). It needs to provide constructs that allow a description of the relevant aspects of the work process.

Independently of the aspects to be represented, the language deployed in steps 2 and 3 needs to adhere to certain structural requirements in order to facilitate alignment activities (cf. *MSF 1* and *MSF 3*). The modeling language can support the consolidation process by providing structural guidance. In line with the work of Türetken & Demirörs (2011), guidance measures are incorporated in the modeling notation in order to make visible the parts of the individual models that are subject to negotiation during the consolidation process, and which parts should remain the genuine responsibility of the contributing individual (cf. modeling areas and elements for modeling individual aspects and aspects to be consolidated in Figure 2.8).

2.4.3 Instantiation Process of Design Pattern

When instantiating the design pattern shown above, the meta-requirements need to be discussed in all three steps of the proposed method design. In implementing a structured method engineering process (Goldkuhl et al. 1998), each step needs to be specified in terms of *co-operation forms*, *procedure*, *concept*, and *notation*.

Instantiation step 1 focusses on the deployed *co-operation forms*. While in general the design pattern already specifies a collaboratively implemented modeling process, its actual form might vary (e.g., in terms of spatial distribution of modelers or technical support). Instantiation needs to make sure here, that method step 2 adheres to AR1 (individual articulation) and method step 3 adheres to AR4 (explicitly making visible different viewpoints).

Instantiation step 2 has to specify how method step 1 is being implemented (*concept*) and which *notation* and *procedure* is used to meet AR2 and AR3 as well as MSF 3. With respect to MSF 3, the notation in particular needs to be selected in a way that does not force modelers to use specific predetermined semantic categories.

Instantiation step 3 determines the focus of articulation for method steps 2 and 3 (*concept*). This specifies the aspects of work that are subject of articulation and alignment. When the focus is determined, specific *notation*al elements are selected to meet MSF 2. In order to not violate AR 4, the notational elements that are subject of discussion during consolidation in method step 3 need to be determined.

Instantiation step 4 builds upon concept and notation for method steps 2 and 3 specified before and determines the *procedure* of method step 2. In order to adhere to AR 1, the modeling procedure needs to be implemented individually by each modeler without any interactions with others. The methodological guidance in this step should take into consideration MSF 1 (start with case-based modeling) and MSF 4 (scaffolding).

Instantiation step 5 finally needs to determine the *procedure* of method step 3. This procedure needs to pick up the modeling results of method step 2, explicitly make visible in which aspects they represent divergent views (AR 4), and enable their alignment to develop a shared understanding (AR 3). MSF 4 should be taken into consideration again in order to allow for adaptive modeling support measures (scaffolding).

The following section reports on one specific instantiation of CoMPArE, which has been designed for the articulation and alignment of work processes. It implements the three method steps specified here and extends the approach by a fourth step that allows for elaboration of the (case-based) models created during articulation and alignment. This further contributes to the development of a shared understanding and thus is in line with AR 2. The focus on the procedural aspects of organizational work allows to validate the alignment results in terms of AR 4 and AR 3 by enacting the work process models in a virtual execution environment. This additional step thus extends the original design pattern and provides a gateway toward techno-centric models that can be directly used in business process management or information system design.

2.5 A methodology for work process articulation and alignment[7]

The CoMPArE design concepts are instantiated in the CoMPArE/WP method. The "/WP" represents "work processes" as being the selected foci of articulation and alignment. The CoMPArE design is extended by a mechanism that allows for elaboration of the developed models by interactive virtual execution. For appropriate use cases, this enables validation of the developed models and develop them further towards comprehensive models for business process management or information system design.

In the following, the framework introduced by Goldkuhl et al. (1998), which has already been mentioned above, is used to describe about the method and its implementation in detail and show how it can be used for business process design. Goldkuhl et al. (1998) suggest to consider the following aspects when providing a structured description of a method following a question-oriented paradigm: A method builds upon a *perspective* it adopts to determine on what it wants to achieve ("What is important?"). It consists of different *method components*, which are characterized by three closely linked aspects: *procedure* ("What questions to ask?"), *concepts* ("What to talk about?"), and *notation* ("How to express answers?"). The method components together form a methodological structure that is referred to as *framework* ("How are the questions related?"),

[7] Partially taken and adapted from (Oppl 2016a) and (Oppl & Alexopoulou 2016). The full articles are included in chapters 3 and 4.

which describes how those aspects are interrelated and also determines how the method components are linked with each other. A method is implemented by *co-operation forms* (Who asks? Who answers?). In the following, the description of CoMPArE/WP is structured along these aspects. It starts with an overview of the whole method, and subsequently details on each component.

2.5.1 Perspective

CoMPArE/WP adopts the perspective on modeling support argued for by Zarwin et al. (2014) and consequently aims at closing the gap between anthropo-centric (natural) modeling and techno-centric (formal) modeling. To achieve that, it adopts the principles of natural modeling but at the same time it supports in a well-defined way the derivation of executable models. The leading question to be answered by the participants implementing the method is: “How is a business process to achieve a given organizational goal (to be) implemented?”

2.5.2 Framework

The methodology design is informed by a multi-component framework that enables process participants to gradually develop a comprehensive model of their business process in a cooperative way without requiring them to be familiar with techno-centric modeling languages.

The methodology of CoMPArE/WP comprises three related method components as depicted in Figure 2.9.

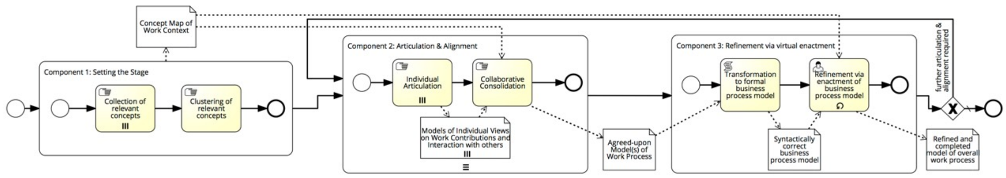

Figure 2.9: The CoMPArE/WP method represented as a BPMN process

These components aim at enabling modeling practices adhering to the principles of natural modeling in the initial phases of business process elicitation and then gradually developing more sophisticated techno-centric models without confronting users with their complexity. An overview of these components is provided in the following. More detailed descriptions of the component are provided in the following subsections, describing them to the level of actual implementation. Component 1 instantiates step 1 of the CoMPArE design pattern. Component 2 covers steps 2 and 3 of the design pattern, distinguishing between “individual articulation” (step 2) and “collaborative consolidation” (step 3). Component 3 extends the development of a shared understanding to more generic cases and enables the transition to techno-centric modeling scenarios.

- *Component 1*: Setting the Stage
  - *Procedure*: What is important in the context of the business process?
    - *Concept*: When implementing this component, modeling participants try to find a common understanding about the scope of the business process and the notions to use to refer to the relevant concepts. Scope herein refers to where the business process starts, where it ends, and which aspects are to be addressed when implementing it. Groups of modeling participants with heterogeneous backgrounds in particular might have an issue with wording when aligning their different views. The notions used to refer to different aspects of the business process are thus explicitly captured.
    - *Notation*: A semantically unconstrained notation similar to concept mapping is used in this component to allow modeling participants to express their concepts without requiring them to initially adapt to a given modeling language.
- *Component 2*: Articulation and Alignment
  - *Procedure*: How do we / should we (the modeling participants) collaborate to implement the business process in our organization?
    - *Concept*: Modeling participants are required to collaboratively agree upon who should be involved in implementing the business process, what contributions the participants are expected to make in the course of the business process, and how they will interact to achieve their goals. Participants are flexible and how they semantically address those three categories but ultimately need to agree upon a common set construct semantics. The description of the results is restricted to a single case of implementing the business process, thus reducing complexity of its representation in this component.
    - *Notation*: Due to the simplified semantic requirements, component 2 makes use of a simplified, generic notation for describing collaborative business processes, which will be further elucidated in the following paragraphs. This generic notation enables semantic adaptation to the requirements of the modeling participants.
- *Component 3*: Refinement via Virtual Enactment
  - *Procedure*: How should the business process be implemented to appropriately address the potentially different contexts it is executed in?
    - *Concept*: Modeling in component 2 focuses on a single case of the business process to reduce complexity of the modeling and alignment procedure. Component 3 conceptually addresses this shortcoming by elaborating the model in an interactive way towards a comprehensive representation of the business process. This is achieved through refinement during virtual enactment, i.e. engaging modeling participants in identifying problems and gaps of their initially agreed upon model by playing through it and elaborating it concurrently.
    - *Notation*: In component 3, no graphical notation for supporting modeling is used at all for the participants. They use web-based dialogue forms to describe

deviations from the business process developed in component 2. Technically, these deviations are incorporated in a BPMN model of the process, which is maintained in the background.

The whole modeling framework is iterative, enabling the flexible combination of design components as the shared understanding about the business process evolves over time and potentially uncovers additional aspects to be addressed. Flexibly combining the three components enables the adaptation of the design procedure to the business process at hand (higher complexity requires more overall iterations), to the amount of divergent views that is present in the group of modeling participants (more divergence requires more iterations of component 2) and to their skills in abstraction and modeling (higher skills enable more complex changes to be made during virtual enactment). Selecting the appropriate steps in an ongoing design process is the task of a modeling facilitator. The selection is made based on the observed situation in the group of the modeling participants and the desired outcome in terms of elaborateness of the resulting model.

2.5.3 Co-operation Form

All components are carried out in a workshop setting, where the modeling participants work on creating a shared artifact. However, component 2 comprises an initial step of individual activity without any interaction to capture the different participants' views on the business process, before collaboratively consolidating those views to an agreed upon model.

The methodology enables process participants to gradually develop a comprehensive model of their business process in a cooperative way without requiring them to be familiar with techno-centric modeling languages. As in participatory design (Kensing & Blomberg 1998), in CoMPArE/WP process participants are actively involved in process design. They articulate their individual views on a work process to eventually cooperatively develop an agreed-upon business process model. Modeling practices used in this methodology, are not performed sitting in front of a PC screen, using some kind of software for process modeling. Instead, participants use cards with different colors which are assigned specific semantics during the modeling procedure. Like in card sorting (J. R. Wood & L. E. Wood 2008), participants create conceptual structures using the cards. Employing tangible means to conduct process modeling has already been proposed in the literature (Luebbe & Weske 2011; Oppl & Stary 2014). Using tangible means like cards instead of sophisticated software allows also technologically illiterate workers or, in general, workers that do not feel comfortable with technology to take part in modeling and overall makes modeling more enjoyable and appealing to modeling participants.

An example for the activities in component 2 is given in the following to demonstrate the implementation of the articulation and alignment process.

2.5.4 Example for Articulation and Alignment

Component 2 contains two sub-components, namely “Individual Articulation” and “Collaborative Consolidation”. This separation of individual articulation and collaborative consolidation facilitates knowledge sharing and promotes negotiation and commonly agreed-upon decisions. The consolidation process leads to the documentation of a shared understanding about the business process, in accordance with the second principle of natural modeling.

Existing research (Santoro et al. 2010; Fahland & Weidlich 2010; Kabicher & Rinderle-Ma 2011; Lai et al. 2014) suggests that starting modeling based upon a concrete work case makes it easier for process participants to develop an understanding of the concepts necessary to describe a work process in an abstract conceptual model. The leading question for this component is: “How do we / should we (the modeling participants) collaborate to implement our work process in the organizational context?”

Component 2 requires modeling participants to collaboratively agree upon who should be involved in implementing the work process, what contributions the participants are expected to make in the course of the work process, and how they will interact to achieve their goals.

For implementing the components described above, the participants are provided with cards of different colors for modeling. Each activity is represented by a red card, named by the participant to indicate what the activity is about (referred to as WHAT-item in the following). The cards are placed vertically below the blue card representing the participant’s own role. Their vertical ordering indicates their sequence, the top-most card consequently representing the first activity of the participant. For each collaboration partner, a named blue card is placed next to the blue card representing him or herself (referred to as WHO-item in the following). All blue cards are arranged along a horizontal line at the top border of the modeling surface. For each exchange, a yellow card is placed vertically below the blue card representing the respective collaboration partner (referred to as EXCHANGE-item in the following). The cards are vertically arranged to match the activities, for which the exchange is required or by which it is provided to others. Yellow cards indicating required exchanges are connected to the red cards representing the dependent activity using an arrow from the yellow to the red card. Provided exchanges consequently are indicated by an arrow from the respective red card to the yellow card.

The spatial arrangement of the cards based on their colors acts as a structural scaffold, guiding the consolidation process in a structured manner via dedicated areas for describing different aspects of the process (cf. Figure 2.10). Scaffolding is a concept widely used in education to describe structures or methodologies that support learners in self-directed efforts to understand something new (Van de Pol et al. 2010). The scaffold used in individual articulation supports modeling participants in describing independently of each other their own activities, the actors or organizational entities they are interacting with, as well as how this interaction manifests itself in terms of information or artifact exchange and enables them to use the same elements for consolidation. Consolidation is performed according to the following scheme (modeling steps described to in brackets refer to the example depicted below):

One of the modeling participants starts by placing the WHO-item representing him/herself on the shared modeling surface. If known a-priori, the actor responsible for starting the real-world business process starts modeling (cf. step 1 in Figure 2.11). The process start is indicated by an individual model, which contains WHAT-items that are not dependent on any EXCHANGE-items to be received. If more than one such individual models exist, this indicates a business process with multiple parallel starting activities, which are only synchronized at a later point in time. In such cases, any of the affected modeling participants can start modeling.

The same participant describes his/her own contribution to the business process by placing WHAT-items below his/her own WHO-item. Others do not intervene during this stage (cf. steps 2-3 in Figure 2.11).

As soon as the participant places the first EXCHANGE-item (step 5 in Figure 2.11), the targeted communication partner steps in and matches his/her own perception of the business process (steps 6-8). Matching can take the following forms:

The communication partner has a matching EXCHANGE-item (i.e., an EXCHANGE-item that matches the already placed item). In this case, the matching elements are merged (cf. steps 19-20 in Figure 2.11).

The communication partner has no matching WHO-item (i.e., he/she has not perceived any collaboration with the original modeling participant at all). This is a fundamental difference in the perception of the business process. Participants need to agree, how to resolve this issue (cf. steps 15-16 in Figure 2.11, where the stock manager expected to receive a parts list from the production manager directly, whereas the production manager passed it on via the production worker).

The communication partner has no matching EXCHANGE-item (i.e., he/she did not share the perception of collaboration or did not consider it relevant). Such a difference again needs to be resolved by the affected participants (cf. step 22 in Figure 2.11, where the production worker considered to be finished after the order was produced, whereas the production manager expected an explicit notification that the production was finished).

The communication partner considers one of the his/her own EXCHANGE-items to match. The involved participants, however, have a different understanding of the content or form of the exchanged information or artifact. Such differences need to be addressed by the participants (cf. steps 5 and 8 as well as steps 11 and 14 in Figure 2.11, where in the first case the production manager provided a more detailed description of the EXCHANGE than the production worker, and in the second case the EXCHANGE between stock manager and production worker was modified due to upfront communication of the parts list).

Consolidation continues in this way until all points of collaboration are agreed upon. When one actor has completed his or her contribution, others with remaining elements not yet incorporated in the common model take over and provide further input to the consolidation process (cf. step 22-23 in Figure 2.11).

The limited set of modeling elements used in component 3 prevents the occurrence of co-operation and externalization problems due to lack of participants' experience in modeling (Genon et al. 2011; Britton & S. Jones 1999). When actively involving process participants, it seems to be appropriate to limit the number of available modeling elements a priori to those appropriate for the intended modeling perspective and targeted outcome (Muehlen & Recker 2008), i.e., case-based models of business processes, as in scenario-based elicitation techniques. In this way, models are kept simple and comprise the most fundamental constructs used for the description of work and therefore the first requirement of natural modeling is met ("i.e. intuitive constructs").

Figure 2.10 shows three sample models created individually in component 2.1, which together form a foundation for later consolidation. The labels in the models refer to a (exemplary) production process, in which a production manager, a production worker and a stock manager are involved. The models indicate several fundamentally different understandings of how the production process should be implemented. While those differences might not occur in such a drastic way in reality, the scenario has been chosen to illustrate different aspects of consolidation below.

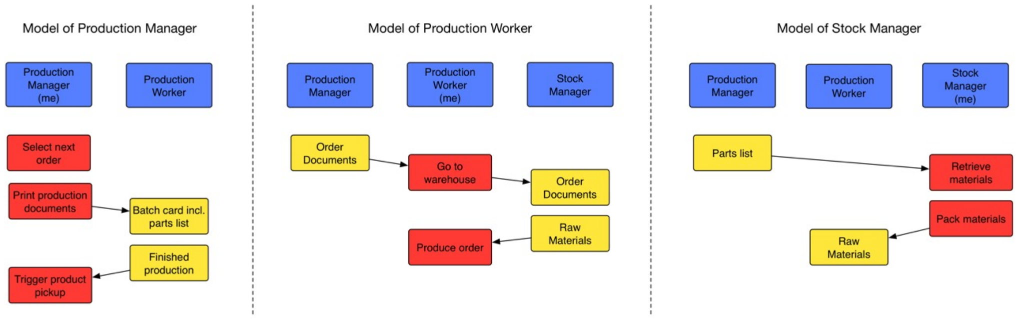

Figure 2.10: Result of individual articulation

The resulting models of component 2.1 are consolidated into a common model in component 2.2. Figure 2.11 shows the merging process for the sample models depicted in Figure 2.10. The numbering indicates the sequence of consolidation steps, the outlines of the numbers indicate the different modelers, and the stroke of the outline indicates whether conflicting viewpoints needed to be resolved.

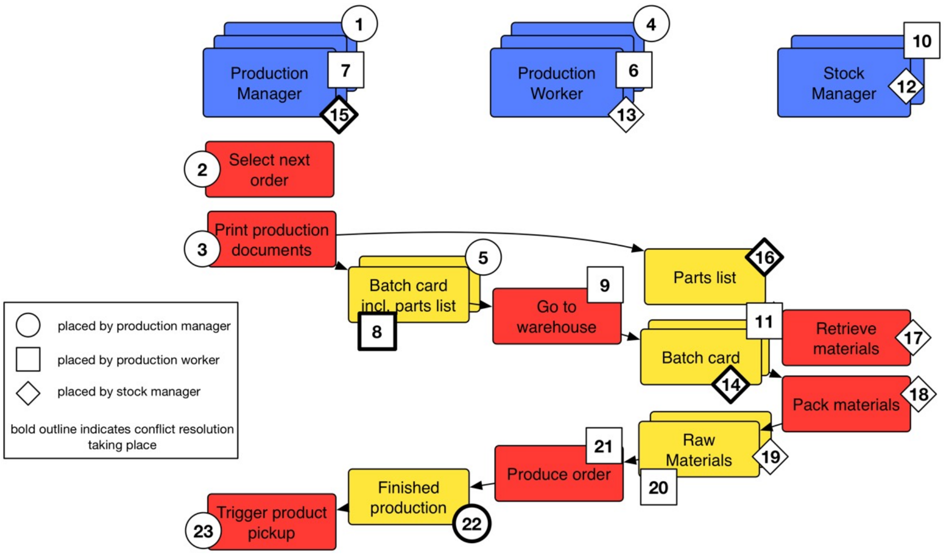

Figure 2.11: Result of collaborative consolidation

2.6 Instruments for incorporating articulation results in enterprise architectures

The two artifacts discussed in the following have been developed as technical means of support to enable the implementation of the methodology described in the former section.

They provide the gateway from non-formalized articulation and alignment activities prevalent in the initial stages of the proposed methodology to activities focusing on the creation of models representations of work that can be processed in information systems, thus contributing to modify the ostensive aspects of organizational work encoded in existing enterprise architectures.

2.6.1 Recognition of paper-based conceptual models[8]

The methodology described above used paper-based modeling techniques for articulation and alignment activities of organizational actors. Its final stage, however, requires a digital representations of the created conceptual model that can be enacted to validate its appropriateness and elaborate it where necessary. In order to enable seamless integration of articulation, alignment, and elaboration, manual transformation of the paper-

[8] Partially taken and adapted from (Oppl et al. 2016). The full article is included in chapter 7.

based models to according digital representations should be avoided. Furthermore, extensive technical infrastructure required for capturing modeling information should be avoided to facilitate practical deployment of the methodology.

The artifact developed to solve this problem thus has to meet the following requirements: (1) The artifact must not require technical infrastructure beyond mundane devices, such as digital cameras. (2) The artifact has to allow operation by non-technical staff and consequently must not require detailed technical knowledge for setup and use. (3) The artifact has to be technically compatible with the other instruments deployed in the overall ensemble of the methodology. In particular, the data representation for models has to be identical, and interfaces for interoperability have to be provided. (4) The artifact should enable users to produce identical outcome in terms of created models and modeling documentation as other conceptual modeling tools. In particular, it has to enable to build diagrammatical conceptual models with different types of nodes that can be linked via directed or undirected connections.

2.6.1.1 Artifact description

The developed artifact is a software system that extracts conceptual model information from photos by means of image recognition. The use of the software, however, is embedded in a socio-technical workflow, which is outlined in Figure 2.12 and describes in the following.

Model digitization already is prepared during the modeling process. The proposed capturing artifact needs to deal with an arbitrary set of modeling languages elements, which are not constrained in shape or size. In order to meet this requirement, the elements bear unique visual markers to allow for reliable recognition.

Once the model is created, digitization starts with taking pictures of the model. Pictures do not need to be taken from a particular angle. It is possible to have several pictures, each showing only a part or details of the model. The pictures can be taken with a standard digital camera and subsequently uploaded to the recognition engine via a web platform. As an alternative, a smartphone app can be used to directly upload the pictures.

The recognition engine processes the pictures in a multistep procedure, which is described in more detail below. The first step is the identification of modeling the elements. Starting from the set of identified elements, the connections are identified in the next step. Finally, the recognition engine searches for labels of elements and connections, and extracts them for future reference. The result is displayed in a web platform and can be interactively refined there. This includes adding textual representations of the extracted labels. The final result is encoded as a XML file replicating the conceptual model structure and the visual layout.

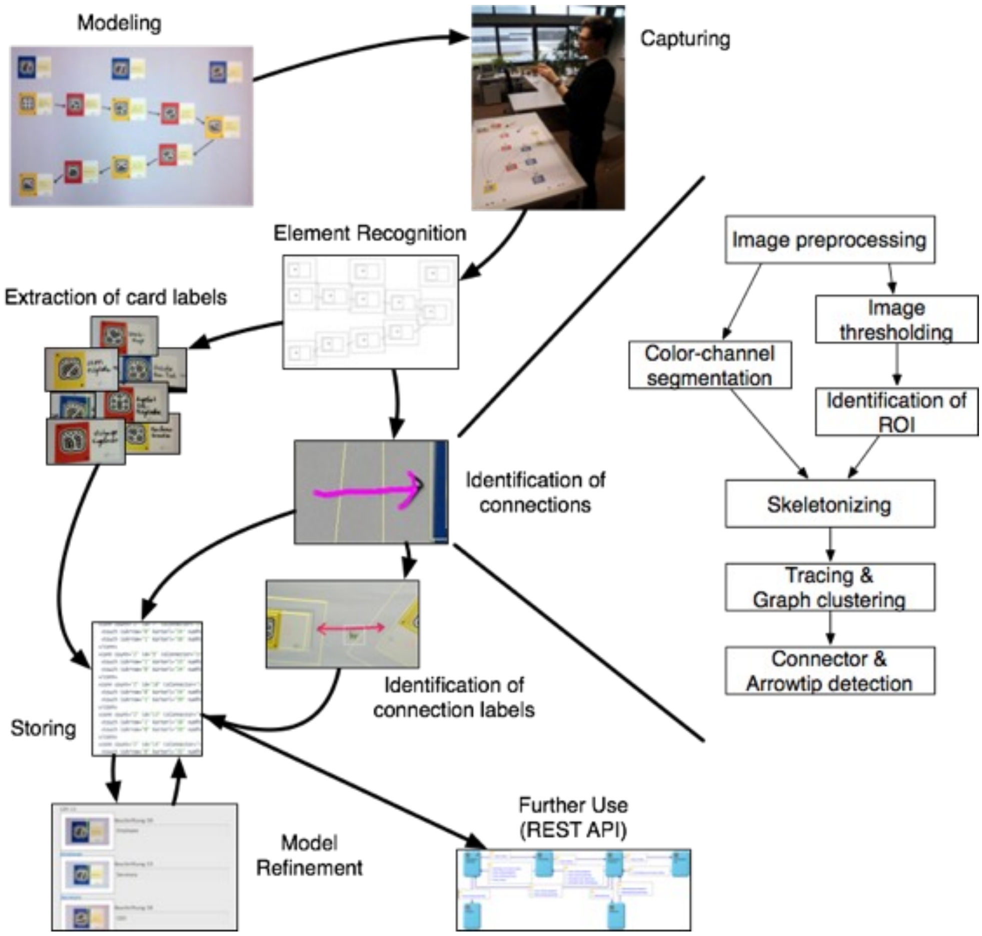

Figure 2.12: Overall workflow for recognition of paper-based models (adopted from (Oppl et al. 2016))

Further processing can in principle be performed with various tools. This includes model visualization, model editors, or post-processing software that interprets the results according to their conceptual or visual structure. The latter is deployed in the present use case, where the recognized model structures are transformed to executable process models for use in the artifact providing functionality for elaboration through virtual enactment. The transformation process is described in detail in (Oppl 2015).

2.6.1.2 Results

The developed system can be operated by end users with commonplace capturing devices such as smartphone cameras. The model digitization engine has been designed to process such pictures and provide the results in a format that is interoperable with other artifacts in the overall system environment, in particular the workflow execution engine that enables model elaboration through virtual enactment. The system has been evaluated regarding its recognition quality and the required effort to compensate for potential recognition errors in a quasi-experimental setting. These results show that the system has achieved its fundamental aims, while still being negatively affected by some technical limitations of the implementation of the recognition engine. Both, capabilities and limitations, also could be confirmed in a field study. The proposed artifact advances the state of the art by introducing an approach for extracting conceptual model information from paper-based sketches captured under uncontrolled conditions in a fully integrated, directly deployable system.

2.6.2 Elaboration through virtual enactment[9]

Completing the articulation and alignment phases of the proposed methodology leads to models that are semantically incomplete representations of a work process. Most notably, these models do not account for different variants of a work process that are represented using decision elements in other business process modeling languages. Articulation and alignment deliberately follows a case-based approach to reduce model complexity for the targeted inexperienced modelers. A comprehensive model of the work process, however, is still required for further processing. For this reason, the case-based models are elaborated interactively using process enactment tools, which play through the work process step-by-step and alter and extend the model whenever the enactment is incorrect or incomplete with regard to the perceived real-world work process. It should be stressed at this point that participants during the virtual enactment do not perform modeling. At this stage, they interact with a BPMS (business process management systems) implemented for this purpose within our research (Kannengiesser et al. 2014). This BPMS presents web-based dialogue forms to the participants, allowing them to describe the deviations from the currently enacted process. The BPMS supports the description of the new or altered process steps by providing the current process context (i.e., what was done, before the deviation was started), as well as information about potential interaction partners.

2.6.2.1 Artifact Description

Models without syntactic errors can be directly used for virtual enactment in the BPMS. For this purpose, an instance of the process derived from the original model is started. As stated above, this model initially only reflects one single variant of the process, omitting more sophisticated control flow constructs such as decisions or loops. The aim of elaboration through virtual enactment is creating a semantically correct representation of the work process in all its variations as perceived by the involved actors.

The actors enact the process step by step. For each step the responsible actor assesses whether the step is correct and described in sufficient detail and whether the

[9] Partially taken and adapted from (Oppl 2016a). The full article is included in chapter 3.

next step is the only possible way to progress or if there are alternative ways of continuing with the work process. This can refer to alternative options of progressing, optional activities or activities that have been omitted in the original model. The model is altered if any of these assessments lead to the need for changes in the process. The BPMS directly accesses the modified model representations and continues with the execution.

Changes can have different effects that might trigger the need for further changes in the overall process. Potential changes in ascending order with respect to their impact on the overall process are described in the following. The nomenclature of the modeling language described above is used for reasons of consistency: (1) adding, altering, or removing WHAT-items to a WHO-item, (2) shifting responsibilities for WHAT-items between WHO-items, (3) altering the sequence of EXCHANGE-items between WHO-items, (4) adding or removing EXCHANGE-items required from or provided to another WHO-items, and (5) involving a new WHO-items in the process.

Case 1 refers to situations where only the behavior of a WHO-item is altered without affecting its interfaces to other WHO-items. Content, form, and sequence of EXCHANGE-items remains unchanged. In this case, the changes only affect one WHO-item and do not require further changes. *Case 2* refers to situations where the content, form, and sequence of EXCHANGE-items remain unchanged but responsibilities are shifted from one WHO-item to another. In this case, the affected WHAT-items must be incorporated in the behavior of the target WHO-item. *Case 3* refers to situations where the sequence of EXCHANGE-items is altered but both content and form remain unchanged. In this case the WHO-item partnering in the communication needs to adapt its behavior to fit the new expectations. This might trigger subsequent changes for this WHO-item, which again potentially causes cascaded changes elsewhere in the process. *Case 4* refers to situations where the EXCHANGE-items are fundamentally altered in a way that adds or removes communication acts to or from the behavior of the involved WHO-items. This necessarily causes changes in the targeted WHO-item, as it needs to react to new information or provide information that was not expected before the change. This again potentially causes cascaded changes elsewhere in the process. *Case 5* finally refers to situations where a new WHO-item is added to the process. This requires specifying the communication interface (i.e. the EXCHANGE-items) with this new WHO-item as well as its WHAT-items, if they are known and relevant to the work process. Adding a new WHO-item might have implications on the behavior of the other involved WHO-item, as additional EXCHANGE-items might be required.

If a change to the model triggers the need for further changes (i.e., in cases 2-5), those cascaded changes do not necessarily need to be made immediately. The elaboration of the overall process, however, can only be finished if all open change requests have been resolved.

2.6.2.2 Results

Elaboration through virtual enactment is a means to generate a process description without the need to manually create comprehensive formal process models by traditional conceptual modeling. Separation of models and model changes along the different involved subjects reduces complexity and allows a focus on one actors's behavior at a time. Using the execution engine allows complex decision processes to be modeled by incrementally adding process variants to the model as the enactment continues. Complex models of collaborative work processes are developed in this way without the need to ever translate one's perceptions of a work process to abstract process descriptions.

It is important to note that the resulting model not necessarily is complete or valid in terms of representing organizational reality. The completeness and objective validity of the resulting model is constrained by the limited views of the involved actors on the overall organization. Non-operatively involved internal or external stakeholders — due to their position — might be able to articulate further relevant aspects about the work process. Involving them in the consolidation and elaboration process or having them validate the results of either phase can address this issue, if a more comprehensive process representation is required from an organizational perspective.

2.7 Evaluation of designed artifacts

The aim of this section is to give an overview of how CoMPArE/WP has been evaluated regarding its use by operative actors to construct a shared understanding of their collaborative work processes and its ability to provide results that are useful for further processing in organizational or technical work support systems. Such evaluations imply the existence of a shared work context for the involved actors in which different views in collaborative work can emerge. This shared work context, however, cannot be controlled or artificially created, as would be necessary for an experimental setup. Case study research (Yin 2009) thus remains a suitable validation strategy.

CoMPArE is not restricted to a particular professional domain but aims at facilitating the collaborative construction of a shared understanding about work processed in a generic way. A multiple-case design is necessary in order to validate this claim. The cases need to be selected from different professional domains, reflecting the diverse range of the potential backgrounds of the participants.

An overview about the evaluations carried out in different domains is given in the following subsections. The detailed results of these evaluations and their in-depth discussion are not included here and are available in the articles the studies have been originally published in (cf. chapters 3-7, detailed references given in the subsections). Before the deployment of CoMPArE/WP in different domains is summarized, the requirements on evaluation methodology are discussed in the next subsection, in order to establish an appropriate assessment framework for the observed articulation and alignment processes.

2.7.1 Methodological considerations[10]

The aim the proposed modeling methodology is to facilitate the alignment of different viewpoints on how collaborative work is implemented in organizations. The proposed collaborative articulation approach facilitates a process of collaborative construction of knowledge about work processes, and it involves all actors that are participating in the respective modeling activity. In order to appropriately examine the process of articulation and alignment, an evaluation method explicitly focusing on these aspects needs to be deployed.

Examining processes of conceptual modeling is an area of research that has gained momentum in the last years (Claes et al. 2013; Soffer et al. 2012). Research has started to examine how facilitation of modeling processes can support the evolution of common ground (Hoppenbrouwers & Rouwette 2012). In this line of research, several efforts have been made to qualitatively describe the effects occurring during modeling (Rittgen 2007; Seeber et al. 2012). The modeling process is considered as a series of negotiation acts among actors, with the model being an artifact generated as an outcome. Evaluations of the process of modeling consequently focus on depicting and analyzing the observed negotiation acts and their impact on the model. Other approaches focus on the process of model creation and collect their data solely from observing the manipulation of the model (Pinggera et al. 2012; Sedrakyan et al. 2014).

These approaches examine different aspects of how the actors negotiate to reach a common understanding about content of the model. Existing research (Gemino & Wand 2003; Krogstie et al. 2006; Mayer 1989) indicates that further potential for evaluating collaborative modeling processes can be found in examining an actor's understanding about a modeled topic and how this its development is facilitated during modeling. These works argue for the need of assessing the development of understanding about the modeled topic, as the understanding of a topic ultimately affects the actions performed in the real world (Seel 2003). The process of collaborative modeling itself, however, not yet has been investigated with respect to how the involved actors articulate their individual views about the modeled topic and how they develop a common understanding.

For the present work, an approach has been developed that addresses this gap and considers collaborative modeling as a process of knowledge articulation and alignment. It adapts an evaluation methodology that has been proposed in the area of technology

[10] Partially taken and adapted from (Oppl 2016b). The full article is included in chapter 5.

enhanced learning (Weinberger & F. Fischer 2006), where articulation and alignment has already been adopted as a perspective when evaluating collaboration processes.

The objects of investigation when examining articulation and alignment processes are the statements made about the topic by the actors during collaborative modeling. In order for the approach of Weinberger & F. Fischer (2006) to be applicable, the units of analysis must be segmented to form epistemologically self-contained statements, i.e., refer to a single aspect of the topic. In addition, in the context of collaborative modeling, acts of modeling, which not necessarily are accompanied by verbally articulated statements, also need to constitute distinct units of analysis. The identified units of analysis are classified along different analytical dimensions as described in the following.

The interaction of the involved actors during collaborative problem solving is assessed in the following dimensions (Weinberger & F. Fischer 2006):

- Actor Participation
- Epistemic nature of statements
- Argumentative quality of claims
- Social Modes of Co-construction

The classification categories specified in these dimensions are interpreted with respect to their application in collaborative modeling settings in the following. In addition, the present chapter extends the methodology to also assess manipulations of the model. This allow to put the social interactions among the actors in the context of their modeling activities.

The *participation dimension* refers to the amount of contributions made by the actor. This includes two aspects: the quantity of participation for each actor and the heterogeneity of participation, i.e., the amount of turn taking happening during the modeling process. Participation is not limited to utterances (verbal or written, depending on the source of the analyzed material) but also includes manipulations of the model.

The *epistemic dimension* refers to the quality of contributions made in one unit of analysis. Each unit of analysis is classified in a single category. The following scheme is used for classification: An initial distinction is made between on- and off-task statements. Off-task statements comprise all statements which are content-wise not related to the topic of modeling. On-task statements are distinguished based on their content. Following Weinberger & F. Fischer (2006), statements can refer to: (a) the problem space. Statements in this category refer to the concrete case that is currently articulated or discussed; (b) the conceptual space. Statements in this category refer to generalizations of a concrete case and cover theoretical considerations about the generic aspects of the current issue; (c) the relationships between problem and conceptual space; and (d) the relationships between the problem space and prior knowledge. Statements made in this category link case-specific statements to prior knowledge of an actor.

The *argumentative dimension* focusses on contributions to problem inquiry and resolution observable in the units of analysis. All claims made by the actors are identified for analysis. Each unit of analysis either constitutes a non-argumentative move or an argumentative claim. Claims can be qualified or grounded. Actors explicitly limit the validity of qualified claims validity through describing the context in which the claim is assumed to be valid. Grounded claims are argumentatively backed by the actors through further justifications, which explain why they are assumed to be valid. Claims can also have both qualities, or exhibit neither of them. The latter cases are considered “simple claims”.

The final dimension of the original approach addresses the *social modes of co-construction*. It classifies the observed discourse with respect to how the actors as a group create align their understanding about the topic and formulate arguments together. Units of analysis that contain content referring to the topic of modeling (as identified in the epistemic dimension) here are distinguished into externalization, elicitation, and consensus-building activities. Externalization refers to units during which actors contributes its own view on the current topic of discourse. Elicitation activities refer to actors questioning others or provoking reactions. Consensus-building can again take different forms. Their identification is described in detail by Weinberger & F. Fischer (2006) and summarized in the following: In “quick consensus building”, contributions of one actor are accepted by the group implicitly or explicitly without any modification and any “indication that the peer perspective has been taken over” (Weinberger & F. Fischer 2006) by the other learners. Quick consensus-building does not give any indication, if knowledge alignment has taken place. “Integration-oriented consensus building” means that actors take over positions of other actors and extend and validate these positions with own input. A unit rated in this category must show statements that “significantly differ(s) from a juxtaposition of perspectives, but indicates a further development of the analysis” (Weinberger & F. Fischer 2006) by an actor. “Conflict-oriented consensus building” is characterized by actors, who not accept contributions of others as they are, but challenge. They require adaptation of the articulated positions in order to achieve a common understanding. Units that should be rated in this category are indicated by “rejection, exclusion or negative evaluation of peer contributions” (Weinberger & F. Fischer 2006), either explicitly or implicitly by ignorance or replacement of a contribution.

The *modeling dimension* describes model manipulations performed by the actors. These manipulations can take different forms, which are informed by those described by Rittgen (2007) for the syntactic level of modeling analysis: (a) adding elements to the model, (b) changing the layout of the model (i.e. rearranging elements), (d) merging duplicate modeling elements or removing them (which is common, when actors contribute individually prepared model elements to a shared model).

These dimensions address different aspects of how actors reach a common understanding about their collaborative work process. In the context of the evaluation of CoMPArE/WP, the actors’ contributions are classified along these dimensions. If CoMPArE/WP reached its aims, i.e., led to explicit engagement with the divergent views on work and facilitated the collaborative construction of a shared understanding of the overall work process, the analysis should confirm the following propositions about the workshop process (structured along the analyzed dimensions): *Participation* shows involvement of multiple actors. Heterogeneity does not contribute to the assessment of the proposition, as the amount of expectable engagement is dependent on the involvement in the actual work process. *Epistemic perspective* mainly shows statements about the problem space (i.e. the actual work case reflected upon). Statements about the conceptual space (i.e. the development of a generic view on a work process) could be observable but are not necessarily to be expected, as the proposed method does not facilitate abstraction. *Argumentative claims* should be grounded and/or qualified whenever conflicting elements are discovered and resolved in the model during collaborative consolidation. Simple claims are to be expected during the articulation of individual views that are not questioned by others. In *Social modes of co-construction*, externalization and elicitation are prevalent when individuals contribute their views on the work process, potentially interrupted by elicitation intervention by others. Whenever conflicting elements are discovered, consensus-building activities should be observable.

The evaluation method introduced here has been deployed in a series of modeling activities focusing on actor-centric organizational development in different professional domains. This study and its results are summarized in the following subsection.

2.7.2 Deployment in organizational development[11]

The evaluation of CoMPArE/WP in organizational development activities has focused on examining the articulation and alignment process. Re-integration of the results in existing enterprise architectures has not been examined in the study, neither on an organizational level, nor on a technical level. Those aspects have been addressed in further studies that are reported on in the following subsections.

2.7.2.1 Focus of evaluation

The articulation and alignment process has been examined regarding its effects on facilitation of the collaborative construction of a shared understanding about a work process. In order to examine whether CoMPArE/WP meets the aim of domain-independence, it has been deployed in multiple modeling workshops in different disciplines (healthcare, social care, industrial production). The unit of analysis for the case study is a group working together in the course of a single modeling workshop. The units of analysis call for an embedded case-study design, in which the relevant aspects of the cases are examined coherently using the same set of empirical methods for each case.

[11] Partially taken and adapted from (Oppl 2016d). The full article is included in chapter 6.

To examine the evolution of an agreement that the common model adequately represents the collaborative work process during the articulation and alignment process, the method developed in (Oppl 2016b) has been deployed. Furthermore, the perceived support in the articulation and alignment process as well as the perceived adequacy of the created representation have been examined using an ex-post questionnaire to be completed by all involved actors. The items of the questionnaire were chosen to cover aspects of collaboration, facilitation and shared understanding as contained in the proposition. The items were formulated based on prior existing work in these areas (Gemino & Wand 2004; Kolfschoten & De Vreede 2009; Krogstie et al. 2006; Recker et al. 2013; Sedera et al. 2002).

2.7.2.2 Cases

The selected cases have all been carried out in the course of vocational training programs that were conducted in the context of the European Union-funded Leonardo da Vinci Project (FARAW; http://www.faraw.eu). Overall, 12 workshops have been documented using the methodology described above, and 175 participants provided answers to the questionnaire used for assessing the perceived outcome of the CoMPArE applications.

The aim of all documented workshops was to provide operative personnel with initial experiences to explicitly reflect on their daily work practices and their collaboration with others. Still, they differ along different dimensions. First, the *professional background of the participants* differed fundamentally. Five workshops were conducted in process-centric production industry with participants used to collaborative work organized along flows of material. Seven workshops were conducted in interaction-centric work settings such as healthcare or social work, were participants are used to plan their work ad-hoc in alignment with perceived requirements of other people. Second, the workshops different in the *amount and quality of support by a human facilitator*. Six workshops were facilitated by people having participated in a facilitator's training, who repeatedly urged participant to use the structural guidance measures described above. Four workshops were facilitated by people having acquired their knowledge about the methodology from textual descriptions. Their facilitation approach in general was more laisser-faire, initially pointing at the structural guidelines but accepting their violation at least to some extent. Two workshops were facilitated by people having received only a brief introduction to the approach, who did not point out any of the structural guidelines when introducing the participants to their task. Third, the workshops differed in the *perceivable added value of their outcome*. In five cases, the participants were not given any indication of the potential impact of their collaboratively created model. In two cases, the participants were explicitly told that their results would be the basis of the future implementation of the respective work process in the whole organization. In the remaining five cases, the participants were told that the results of the workshop should support them in their individual future work.

Three cases have been selected out of the 12 documented cases, representing diverse characteristics along all three dimensions. The workshop for each case was video-taped for later analysis of the articulation and alignment processes. The modeling results in all steps of the methodology were documented as photos. After the participation in the workshop, the participants were asked to complete the questionnaire assessing the perceived outcomes, as described above.

The first case was conducted in an Austrian vocational training school for adults being educated as carers for the elderly. As a part of their education, the students have to complete several internships in long-term care institutions. The first day of these internships is of special importance, as organizational and administrative details are clarified on this day between the students, the care-homes, and the school. The head of the vocational training school observed uncertainties and ambiguities regarding the mutual expectations and requirements of what was to happen on this first day. CoMPArE/WP was used to articulate experiences and expectations by all involved parties and create a shared understanding of what should happen on this day. The workshop was facilitated by two trainers of the vocational training school, who adopted a laizzer-faire approach to facilitation, not enforcing structural guidelines in the method components.

The second case was documented in a workshop carried out in the context of a training session on shop-floor logistics in an industrial production company in Slovenia. The participants were tool-makers, who are concerned with producing and maintaining tools for flexible manufacturing cells. Starting from raw materials, the production, assembly, and maintenance of these tools require multiple steps using different machinery distributed all over the production shop-floor. The tool-makers normally are assigned to one single step in the work process and do not have an overview about the overall process and how their contribution affects the work of others. The aim of CoMPArE/WP was to create awareness of how one's own work is embedded in the overall process, and how coordination and collaboration potentially could be improved. The workshop was facilitated by a foreman, who was a domain expert and repeatedly urged the participant to adhere to the structural guidelines of the CoMPArE/WP method.

Case 3 was taken from a series of workshops conducted in a vocational education school for social workers in the Netherlands. Similarly to the care-workers in case 1, the students spend part of their education in practical trainings in real social-work institutions. The students had spent their internships at different institutions, but all had implemented the same task. Consequently, they shared a common work context but had made different experiences from practice. The aim of the implementation of CoMPArE was to articulate and reflect upon experiences and lessons learned in order to create documentation of what is important when organizing such an event with the involvement of clients. The workshop facilitators not introduce any of the structural guidance measures but only explained the meaning of the modeling elements.

2.7.2.3 Results

The three presented cases have shown the application of the proposed methodology in different professional sectors, with different quality of facilitation and with a different amount of perceivable impact of the outcome for the participants. However, they had in common their application domain of reflective purposes in vocational training. This might limit the generalizability of the findings discussed below. Still, as all cases were conducted in a real world context, they are valid selections for the purpose of this study as outlined in the beginning of this section. The study results are presented in detail in chapter 6 and are only summarized in the following.

In the study of the articulation and alignment processes along the different dimensions introduced in (Oppl 2016b), the following observations could be made: *(1) Participation*: *should show the involvement of multiple participants.* This has been confirmed in all three cases, since all participants actively contributed in each workshop. Whether interaction is sequential or simultaneous depends on the different identified phases during confrontative consolidation. (2) *Epistemic*: *mainly shows statements about the problem space. Statements about the conceptual space could be observable but are not necessarily to be expected.* In general, confrontative consolidation starts with problem-space specific statements, which gradually develop towards more generic statements over time. This claim thus can be confirmed. (3) *Argumentative claims*: *claims should be grounded and/or qualified whenever a conflict in EXCHANGE- or WHO-elements is discovered and resolved in the model during collaborative consolidation.* Argumentative claims are mostly grounded and/or qualified across all three cases when consensus building activities are carried out. Simple claims accompany the whole process, largely in the context of externalization and elicitation activities (i.e., when participants talk about their work without explicitly constraining their statements to a specific case). This claim thus can be confirmed. (4) *Social modes of co-construction*: *Externalization and elicitation is prevalent, when individuals contribute their views on the work process, potentially interrupted by elicitation intervention by others. Whenever conflicts are discovered, consensus-building activities are observable.* In general, this claim can be confirmed for all cases. Interestingly, interruptions of externalization activities hardly could have been observed (with the exception of case 3, where the structured modeling approach has hardly been adopted). Consensus building activities are largely only to be observed in later stages of confrontative articulation, when the externalized models were revisited. This might be attributable to the structured externalization process in cases 1 and 2, which guided the participants through the process of initially creating the common model and which hardly showed any fundamental difference in their perceptions.

The observation results are complemented with the results of the questionnaire. If CoMPArE/WP was perceived useful, the variables of the questionnaire representing perceptions about the workshop process and perceptions about the workshop outcome should show values that is significantly ($p<0.05$) better (i.e. lower) than the scale's median value of 3. For case 1, the questionnaire has shown mixed results to this respect.

This might be explainable with the lack of experience the participants had with their work process and consequently their problems of identifying potential added value of the workshop. Interestingly, the results for case 3, which hardly made use of any of the structural guidance measures provided in the methodology, are also consistently significantly lower than the median value. Ignorance of the structural guidance measures for modeling in case 3 thus led to less understanding of the modeling support measures, while the overall setting still was considered supportive. The perceived relevance and usefulness of the workshop still is significantly positive for case 3, as are the variables referring to the perceived support of the methodology and are similar to the results of cases 1 and 2. This can be interpreted as an indicator that multi-perspective articulation as the fundamental concept of CoMPArE has been recognized to be of value, but the guidance measures still support the understanding of the modeling process (as in cases 1 and 2). The proposition thus can be confirmed in light of the presented results.

These results can also be interpreted in the light of the requirements on the methodology formulated for the design theory:

AR 1, which requires individual understanding to be codified in separate models by each actor and to be consolidated in a separate step, and *AR 4*, in which divergent understandings among the involved actors are identified and explicitly made visible, have been implemented by structural guidance measures (cf. MSF 4 as described in the design theory in section 2.4 and in chapter 3). The empirical results show that in the cases in which the structural guidance measures have been applied, the participants have a better understanding of what they are asked to do content-wise and feel that they gain added value from the application of the guidance measures. The implementations aiming to meet AR 1 and AR 4 thus appear to contribute to the overall objective.

AR 2, which requires that process of alignment is supported in a collaborative setting has been realized by specifying consolidation guidelines to be provided to the actors by a facilitator (cf. MSF 4). This has been the case in all three described cases. All cases expose similar interaction patterns throughout the consolidation process, independently of whether or not the structural guidance measures were applied. This is an indicator for successful implementation of AR 2 in light of the overall objective.

AR 3, which requires to support the development of common ground on the collaborative work process, its scope, and its context has been implemented by providing an actor-oriented, communication-centric modeling language with flexible semantics (cf. MSF 2 and MSF 3 as described in the design theory in section 2.4 and in chapter 3). The modeling results and results for the ex-post questionnaires in the three cases show that this language was largely adequate for the target group and also allowed to represent the relevant issues. Still, the participants were not able to apply a consistent understanding for all modeling elements throughout the whole session. This is not necessarily an issue for the primary aim of the method, for which the models only act in situ as mediating artifacts. However, if they should also be used for later referral, these inconsistencies could pose a challenge, as the exact semantics are not explicitly documented. Overall, AR 3 can be considered to be successfully implemented for the aims of the present work but show potential for improvement to be addressed in future iterations of the methodology.

Based on these results, the overall objective pursued in the present work can be considered reached. Whether or not a shared understanding actually was reached has not been addressed in the study and should be the subject of future empirical research.

2.7.3 Deployment in business process elicitation[12]

Aside the facilitation of articulation and alignment, the aim of CoMPArE/WP is to support modeling processes in a way that lead to models usable in techno-centric applications, such as business process management or information system design. The evaluation reported on in this subsection has focused on the viability of deployment of method in the context of business process elicitation. Details and background of the application of CoMPArE/WP for business process elicitation are given in (Oppl & Alexopoulou 2016) (cf. chapter 4). The following subsections only summarize the results of the empirical study.

2.7.3.1 Focus of evaluation

The goal of validation in the present study is to show that CoMPArE/WP facilitates natural modeling and at the same time enables participants to produce a techno-centric model of the business process. Consequently, validation in this study focuss on the question, whether the final modeling results provide the syntactic and semantic quality of techno-centric models and allow for further processing in IT-systems.

These questions are examined in a case study that demonstrates the implementation of the CoMPArE/WP approach in a real-worlds setting. Methodologically, the validation requires to qualitatively document and analyze both, process and result of modeling in the different method components with respect to the formulated questions. Consequently, the modeling results of the method components 1 (setting the stage) and 2a (individual articulation) were photographed and transcribed to digital versions for easier assessment. The results of component 2b (collaborative alignment) and 3 (virtual enactment) were exported from the used BPMS. The documented results and observations made in the case are used to discuss how the requirements of natural modeling are met while maintaining the bridge towards a technically interpretable business process model.

[12] Partially taken and adapted from (Oppl & Alexopoulou 2016). The full article is included in chapter 4.

2.7.3.2 Case

The case used for evaluation is situated in an organization that undertakes software development projects. At the beginning of every project, the project set-up process is conducted aiming at agreeing upon the project's scope, the relevant stakeholders, the timeframe, etc. The project teams always consist of a set of developers, who are led by a team leader. Ongoing communication with the client is ensured by a dedicated contact person (who might also be a developer). In addition, there are mentors who formally do not belong to the team, but are experienced project managers supporting the project teams and acting as backups, if interventions become necessary.

Representatives of the following roles took part in the workshop: a *team leader*, a *mentor*, the *contact person*, and a *client*. In addition, a facilitator was involved to guide the process methodologically. One observer was present to document the results and the process of the workshop for later evaluation. The workshop was carried out in two parts. The first 3-hour block was dedicated to the first two components of CoMPArE/WP. Based on the outcomes of this first part, a model was built using the CoMPArE/WP language (based on the *who*, *what*, *exchange* constructs). This was used for virtual enactment in the second part of the workshop, which lasted 2 hours.

2.7.3.3 Results

A comprehensive presentation of the evaluation results, including the models created in the different components of CoMPArE/WP, is given in chapter 4. This subsection focuses on the transition from the result of collaborative consolidation to an executable BPMN model (White & Miers 2008) and its use to refine and validate the representation of the work process.

Figure 2.13 shows the agreed upon card-based model of the business process of the collaborative consolidation. The consolidated model shows the business process from an overall perspective.

For virtual enactment, the model shown in Figure 2.13 was transformed to a syntactically correct BPMN model (cf. Figure 2.14). The source model has some semantic ambiguities that hamper direct enactment, as the BPMN model is semantically underspecified.

The affected elements are "TL-c4", "TL-c2", and "Co-c4"/"M-c4", where the exact point in time of EXCHANGE is not specified. In addition, "M-c2 and "M-c3" are not explicitly considered by the client for receiving and sending, respectively, at all. Consequently, the first group of ambiguities was transformed to mutual message flows connected to the respective activities, whereas the second group of messages was transformed to message flows that are connected to the targeted pool representing the client. All other exchange elements were mapped to message flows with corresponding throwing and catching message events.

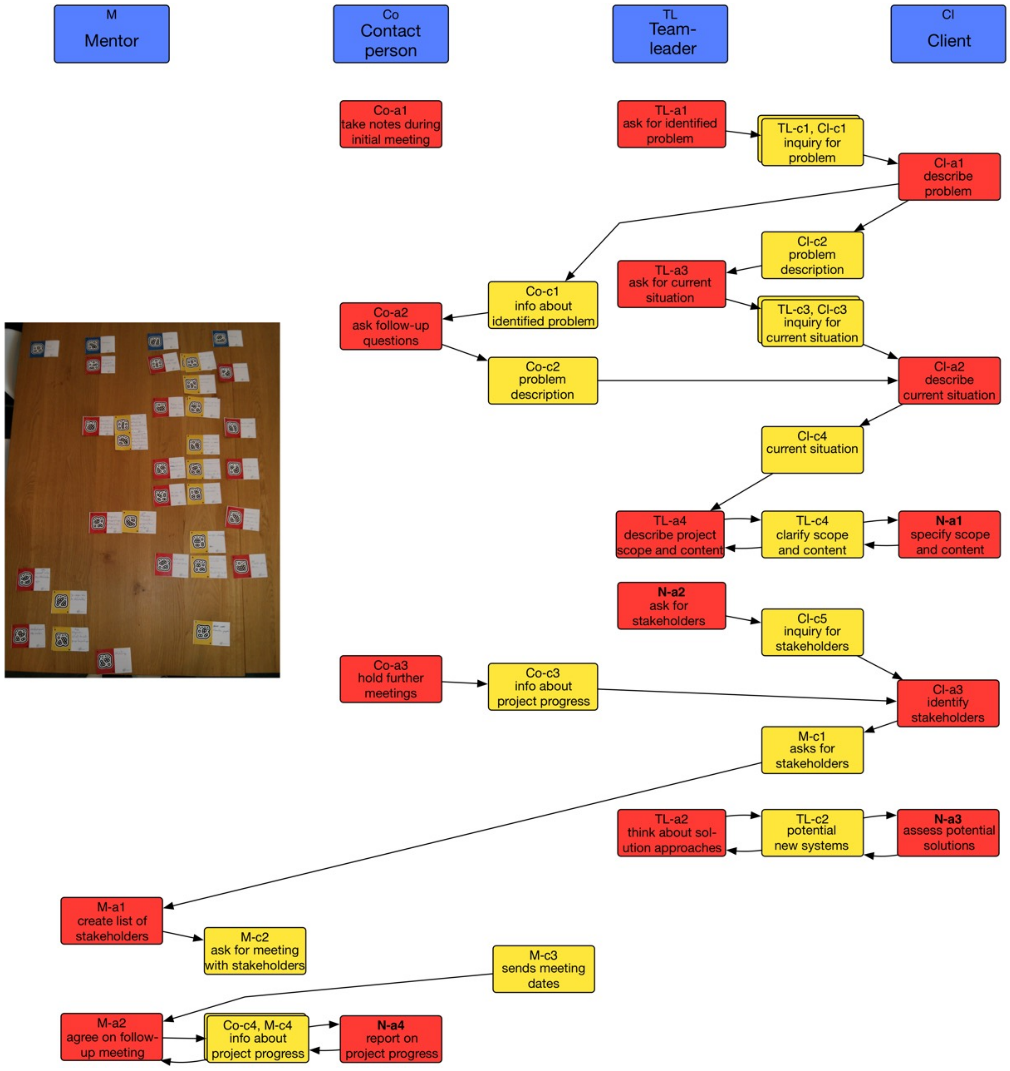

Figure 2.13: Result of collaborative consolidation in case study on business process elicitation

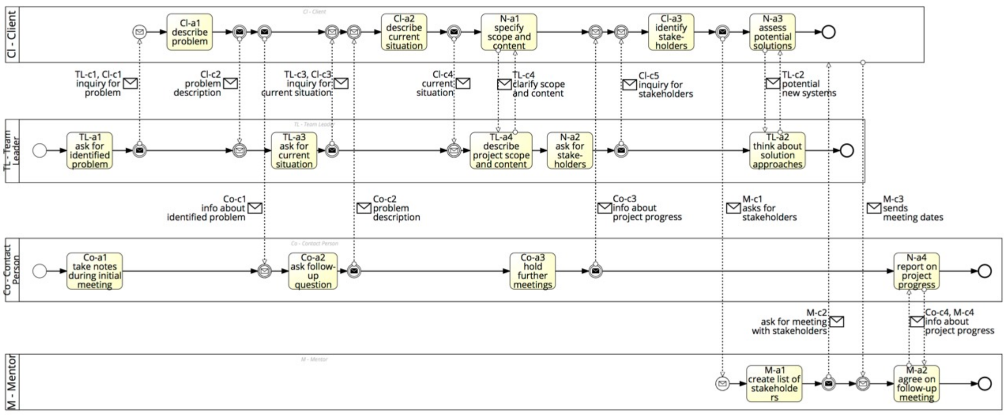

Figure 2.14: Result of transformation to BPMN

This model was used for virtual enactment to identify necessary refinements and extensions of the process model. As an example for refinements through virtual enactment, Figure 2.15 shows the initial refinement step made in the workshop, visualizing the original version of the team leader's behavior on the left and the refined description of the behavior on right. The elements bearing a name starting with "R" have been added during refinement. The refinements in this step do not affect any other pools, thus no cascading changes were necessary.

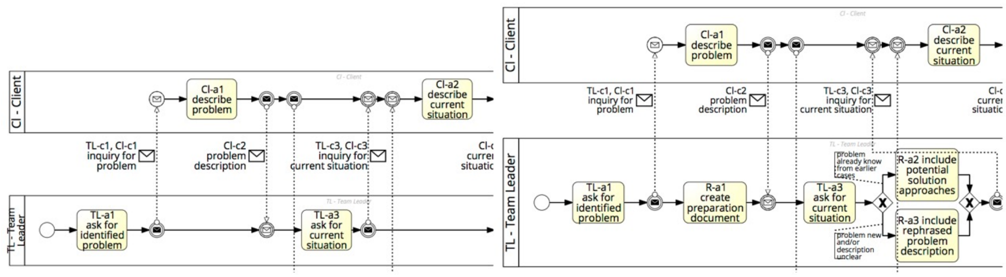

Figure 2.15: Example of refinement (left: original process, right: refined process)

In the later phases of virtual enactment, the semantic ambiguities still contained in the model were resolved. For "TL-c4", "TL-c2", and "Co-c4"/"M-c4", a more detailed description of the communication procedure (to be implemented in future) was created, whereas "M-c2 and "M-c3" were removed, reducing the mentor's role only interacting with the client contact person and the team leader. In making these changes, the model gradually evolved from depicting the as-is-process to depicting a to-be-process, envisioning improvements to the collaboration setup via playing through the process model. The case study was concluded after this first iteration through the modeling and virtual enactment process.

The model resulting from collaborative consolidation in component 2 semantically depicted a single scenario of the complete process and was syntactically compatible to BPMN. The transformation process led to a model that already met the aim of producing a syntactically correct business process model. This model was then used for semantic refinement through virtual enactment in component 3. Only at this point, a semantically fully refined modeling language (BPMN) was used for representing the process. During virtual enactment, the participants, however, were not directly confronted with the BPMN model representation, but performed refinement by describing their additional or altered process steps in the BPMS. The process of refinement, however, was perceived to be cumbersome due to the lack of appropriate tool support in the prototype. Participants had difficulties to appropriately describe their additional process steps appropriately, in particular when additional message exchange was required. Picking up sent messages on the receiving side was confusing for the participants, as the user interface did not appropriately guide them to resolve such temporary process inconsistencies. These situations were resolved by the facilitator but require further research and development.

The case study shows that the method has succeeded in implementing the principles of natural modeling, at the same time leading to the production of a BPMN-model, which can act as the basis for further techno-centric processing. The case study, however, also illustrated challenges in the design process, in particular at the gateways between the methodological components. The role of a facilitator still appears to be of high importance for guiding through the articulation and consolidation process. The major challenge here seems to be prompting participants in a way that facilitates description of their work so that the semantics of BPMN elements the model is transformed to later on is accommodated. This has not been fully successful in the described case, which caused higher effort during transformation to BPMN. Facilitator's guidance appears also to be required for applying correctly the modeling guidelines. It is notable that participants failed to correctly refine the labels of the EXCHANGE elements, after their transformation to BPMN message flows for use in component 3. In component 2, they partially used verbs instead of nouns that are normally used to indicate exchanged messages in BPMN and were not aware of the need to change this until an intervention of the facilitator.

Based on these results, the aim of bridging the gap between actor-centric work articulation and alignment and modeling practices that lead to technically processable work models can be considered reached, although some issues in guiding the model refinement process remain to be addressed in future research.

2.7.4 Deployment in information system design[13]

In the final study reported on here, CoMPArE/WP was deployed to prepare input for informed information system design. Details and background of the application of CoMPArE/WP for information system design are given in (Oppl 2016a) (cf. chapter 3). The following subsections only summarize the results of the empirical study with a focus on the use of the alignment results for shaping user interaction and information exchange in workflow support systems.

2.7.4.1 Focus of evaluation

Evaluation in the present subsection needs to assess whether the resulting models are syntactically valid and semantically sound to enable their technical processing in information systems. Underlying this research questions is the following proposition: The common artifact created during articulation and alignment is a model of the work process as perceived by the actors, where the model is considered to be complete when all actors involved in the model creation process consider their views to be fully represented

[13] Partially taken and adapted from (Oppl 2016a). The full article is included in chapter 3.

by the model. This model can be interpreted by and processed in an IS without further transformation.

The units of analysis to assess this proposition are the modeling result after consolidation and elaboration. The modeling results generated during the application of the methodology thus need to be documented, which represent common artifacts serving as the foundation for further processing: the model generated as an outcome of collaborative consolidation (acting as the baseline for elaboration), the result of the transformation process to an executable modeling language (as the first IT-interpretable model), and the model generated by elaboration through virtual enactment (as the final result). Data interpretation needs to assess the syntactic correctness of these models with respect to the use of modeling language and their usefulness for the indented articulation objective.

Data for the presented case thus were collected following a participant observation approach (Jorgensen 1989) in a revelatory single case design (Yin 2009).

2.7.4.2 Case

The case is situated in the administration department of a university and addresses the procedures necessary to come to a funding decision for research materials or infrastructure. Research departments can apply to receive additional funding from the global university budget, if they are not able to cover the costs of materials or infrastructure for conducting their research.

The process of assessment and decision making for such applications historically was never formally established. This led to a lack of transparency in the decision process regarding both the decision criteria and the status of an application at a given point in time. In this case study, when a new CFO took office she set out to establish this process. The aim of this initiative was to make the progress and outcome of applications transparent to the applicants, and ultimately to have the whole process supported by the already existing workflow management system of the university. The methodology described above was used in a series of workshops to reach these aims.

The methodology initially was applied to reach common ground across all involved organizational entities of the not yet formally established process. The methodology was used to elaborate the model of the application process so that it provided a foundation for setting up process guidelines, forms, and workflow support. Modeling consisted of setting-the-stage, individual articulation, and collaborative consolidation in the initial workshop and elaboration by virtual enactment in a second workshop. A facilitator guided the whole process methodologically but did not intervene content-wise.

Representatives of the following organizational roles were involved throughout the whole articulation and elaboration process (names given in brackets are used as abbreviations when referring to them below). The list of activities refer to the anticipated tasks during the application process that led to the invitation of the respective person to participate in the workshops: *technician of a research department* (technician): filing application for funding, providing additional information as needed; *representative of university IT department* (IT dept.): providing domain expertise for decisions about IT-oriented applications; *CFO of university* (CFO): making final funding decisions, acting as the link to the executive board of the university for decisions on applications exceeding a given financial threshold; *head of controlling* (controller): preparing funding decisions for the CFO, assessing financial feasibility, communicating with the applicant; *head of financial administration* (head of finance): managing the ordering and inventory of material or infrastructure from approved applications.

Of these five actors, only the representative of the IT department had prior knowledge of enterprise modeling. The other actors only had operative experiences with the university workflow management system, without being explicitly confronted with the underlying models.

2.7.4.3 Results

A comprehensive presentation of the evaluation results is given in chapter 3. This subsection focuses on the validation of the consolidated model and its elaboration through virtual enactment.

The result of collaborative consolidation is depicted in Figure 2.16, which shows the original model and a transcribed, anonymized version used for description here (coding scheme for numbers used in transcribed version: x denotes WHO-elements; x.y denotes WHAT-elements, where x is the responsible WHO-element; and x1-x2.z denotes EXCHANGE-elements, where x1 is the sending and x2 is the receiving WHO-element). Numbers in brackets refer to Figure 2.16 following the described coding-scheme.

The model was transformed to a S-BPM process model (cf. Figure 2.17) using the transformation tool as described in chapter 3. Missing information and ambiguities (e.g., EXCHANGE-items 7-1.1 and 5-1.2 lack a target WHAT-item in the lane of WHO-item 1) were identified and resolved during transformation. The facilitator guided this step, as interactive guidance technically was in an embryonic stage and thus could not be operatively deployed. The result was deployed to the BPMS used for the "elaboration through virtual enactment" phase.

The actors having participated in articulation and alignment gathered in a colocated setting with the facilitator and an additional modeler responsible for making changes to the model as required during enactment. The latter was necessary due to the limitations of the current tool prototype used for virtual enactment (cf. chapter 3) and consequently was instructed not to intervene regarding the content.

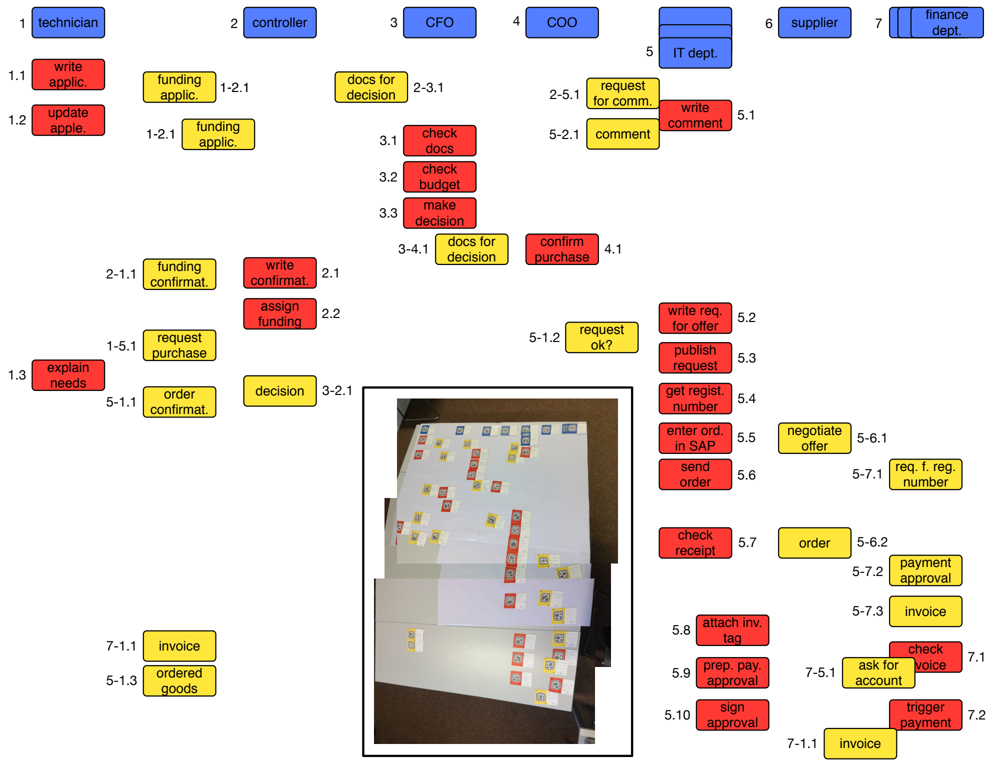

Figure 2.16: Card-based model resulting from collaborative consolidation in case study on information system design

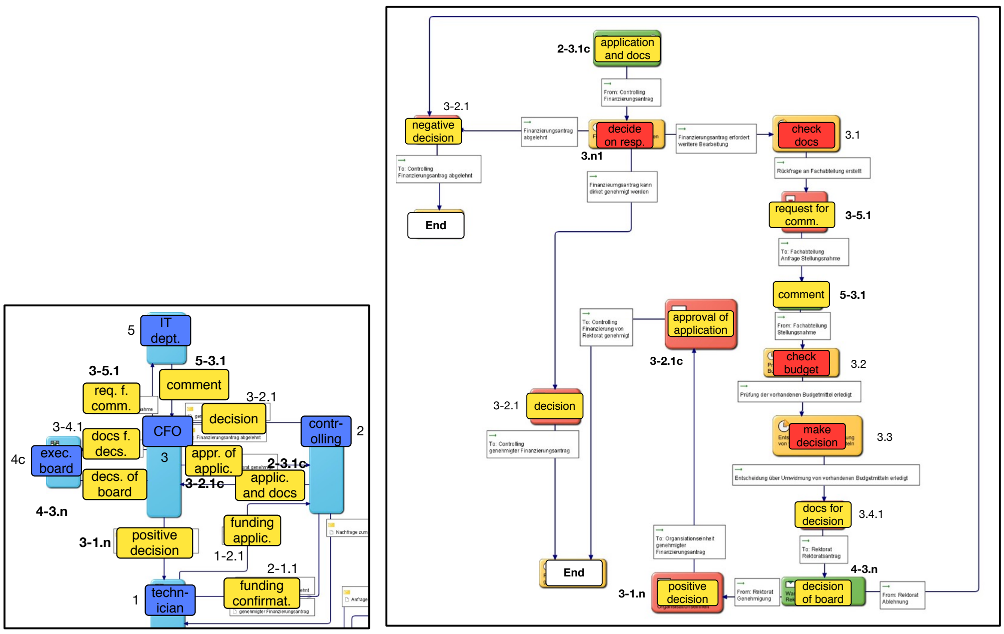

Figure 2.17: Excerpt of S-BPM model representation (already elaborated) – left: part of subject interaction diagram showing CFO's (3) modified interaction (changes printed in bold); right: extended behavior diagram of CFO (changes printed in bold)

Playing through the process contributions of the technician and the controller did not reveal any need for changes or extensions. Major changes to the process, however, were required for the CFO's part, reflected in Figure 2.17 and described in the following (numbers in brackets refer to elements shown in Figure 2.17). The CFO wanted to reflect the criteria for funding decisions in the process model, and she consequently extended the model with a decision element (3.n1) that reflected the different options of coming to a decision for a funding application. These changes to the process model were included immediately during execution and were validated in the same step by executing them iteratively. These changes to the behavior of the CFO triggered cascaded changes as described in Section 2.6.2. An example of such cascaded changes is the addition of the executive board of the university as an additional instance for decision making if the funding application exceeds a certain amount of money (cf. case 5 in Section 2.6.2). In the subject interaction diagram, the existing subject 4 in the consolidated model originally referred to the university chief operations officer (COO), who had to be informed in certain cases. However, this was changed to represent the executive board (4c); The behavior of the CFO affects communication with the executive board (cf. case 4 in Section 2.6.2, reflected in 3-4.1 and 4-3.n in Figure 2.17). In addition, the behavior of the controller requires changes, as decisions need to be prepared differently in such cases (cf. case 3 in Section 2.6.2, reflected by the altered incoming communication 2-3.1c in Figure 2.17). Additionally, the communication with the IT dept. (5) was changed back to be carried out by the CFO (3), as the latter argued that making informed decisions was easier for her if she could interact with the domain experts directly (reflected in 3-5.1 and 3-5.2, which substitute 2-5.1 and 2-5.2 from the result of collaborative consolidation). In addition, the CFO insisted that she should be the one to inform the technician (1) about decisions made by the executive board (reflected in 3-1.n in Figure 2.17). The remaining process was again enacted without any major changes and is not described here in more detail.

After "elaboration through virtual enactment" was completed, the process was transferred to an operative instance of the BPMS. The participants were granted access to this platform to experimentally implement the new process in real-world cases. After a testing phase of three months, a brief reflection meeting was held to allow for mutual feedback and to collect ideas for further improvements to the process. In this step only minor modifications to the sequences of activities of the controller were made, and thus the remainder of the process was not altered. The process was then exported in its final version and provided to the IT department for implementation in the university's global workflow management system.

Feedback of the participating actors shows that making changes during virtual enactment was perceived to be cumbersome. The switch between different model visualizations from card-based consolidation to computer-based elaboration initially made it hard for participants to recognize the semantic equivalence of both models. This issue was resolved, when virtual enactment was started and tracked simultaneously in both model versions. The setting in which the elaboration workshop was held, however, reduced the involvement of the actors in modeling. They took no active role in modeling anymore, and left finding appropriate model representations to the expert-modeler, who was perceived to be responsible for making the model elaborations, although his passive role was clearly articulated. Although none of the actors has claimed this to have a negative impact on the modeling outcome, the validity of their perception is questionable. Observations have shown at least two cases where the actors accepted content-wise changes proposed by only one actor and made by the expert-modeler without questioning them. First, experiments with enabling model elaborations done by the actors themselves during virtual enactment using an interactive elaboration component based on prompting embedded in the enactment environment were made since then. Initial results with this setup were promising but require further evaluation before they can be used in real-world settings.

The aim of generating a model that is a syntactically valid and semantically sound was reached. Analyzing the process of model creation, however, reveals some limitations of the current tool support, which were resolved in the case study by interventions of the facilitator. Future work will have to address these limitations and extend tool support towards providing better procedural scaffolds for model transformation and elaboration.

2.7.5 Summary

Overall, the three studies reported on in this section have shown that the methodological artifact CoMPArE/WP could meet the meta-requriements formulated in the design theory refered to as CoMPArE. Shortcomings could be identified in the area of supporting the integration of articulation results in existing enterprise architectures on an organizational or information system level. While the fundamental principles appear to provide appropriate support in this area, operative socio-technical support during the implementation of the affected methodological steps does not yet seem to be satisfy the requirements of the involved actors.

These issues are currently being adressed in ongoing research. This research is being informed by further studies, that have been conducted on the technical support for transforming articulation and alignment results to IT-processable models (reported on in (Oppl et al. 2016), cf. chapter 7), and on the role scaffolding practices can play in guiding participating actors through the processes of articulation, alignment, and elaboration (reported on in (Oppl 2016e) and (Oppl & Hoppenbrouwers 2016)).

2.8 Conclusion

This chapter has given an overview about the content of the present thesis from a design science perspective. It has discussed the kernel theories underlying the overall research endeavor and has connected the contributions of the original articles, which are presented in the following chapters.

From the global perspective taken in this chapter, the major contribution of the present work is the methodological approach to facilitate multi-perspective articulation and alignment of work process knowledge in IT-processable conceptual models introduced in (Oppl 2016a) and refined in (Oppl & Alexopoulou 2016). The present chapter has elaborated on the generalization of this approach towards a general design theory for supporting work process articulation initially described in (Oppl 2016d) and further discussed in (Oppl 2016c). In terms of IT-support, the enabling artifacts to deploy the methodology are the toolsets for elaborating models through virtual enactment (Oppl 2016a; Oppl 2015) and for recognizing paper-based conceptual models to make them processable by means of IT (Oppl et al. 2016).

In its present form, the research presented here has several limitations. First, the proposed design theory has only been instantiated in a single methodological artifact to support articulation and alignment of process-oriented, behavioral knowledge so far. Its applicability to other aspects of organizational reality remains to be demonstrated. Second, the socio-technical approach of elaboration through virtual enactment has only been validated in two case studies by now. A more extensive validation of the potentials and limitations of the approach, in particular for complex processes with a large amount of communication dependencies among the involved actors, is subject of currently ongoing research and has not been included in the present thesis. Third, the transfer of the methodology to organizational reality with respect to integrating the results into existing enterprise architectures, enabling its sustainable deployment in practice, is not yet addressed in the presented research

These limitations are addressed in currently ongoing and future research. As part of an ongoing research project[14], the issues of deploying the articulation approach to other aspects organizational reality and the effects of model elaboration through virtual enactment are currently being investigated. First results have been presented in (Oppl 2016e) and (Oppl & Hoppenbrouwers 2016). The aspect of integrating articulation results with existing enterprise architectures will be picked up in our research on stakeholder-centered design and support of open enterprise systems, initially reported on in (Stary et al. 2015) and (Stary & Wachholder 2015).

[14] Scaffolds for Work Process Modeling, FWF Erwin-Schrödinger-Fellowship, https://scawomo.wordpress.com

3 Articulation of work process models for organizational alignment and informed information system design[1]

3.1 Introduction

Changes to business processes have an impact on how people work and collaborate within organizations. Being able to quickly adapt business processes to external or internal influencing factors is crucial in today's ever-changing business environments. Remaining competitive in such environments, which are characterized by highly dynamic market requirements and increased employee mobility, is dependent on being able to acquire knowledge about work processes and their context from experienced workers (Aguirre-Urreta & Marakas 2008) and represent it in a way that makes it accessible for and adaptable to future work situations and new employees (Škerlavaj et al. 2007). Representing work processes through conceptual modeling is a recognized means of making them visible and adaptable to changing organizational or business requirements, particularly by using them to design and configure information systems (IS) (Curtis et al. 1992). Failing to involve operative personnel in change projects affecting work processes and IS results in ignorance (Joosten 2000) and ultimately leads to ineffectiveness and unclear responsibilities (H. Shen et al. 2004).

The existing literature (e.g., (Recker & Dreiling 2011; Herrmann et al. 2002) shows that this challenge can be met by involving operative staff in conceptual modeling activities, but also indicates that such an approach introduces challenges in the process of modeling that have to be addressed methodologically. People operatively involved in work processes (referred to as "actors" in the following) are domain experts with extensive knowledge about their respective roles in a work process, but normally have little

[1] This chapter is identical in terms of content to the accepted final version of the article „Oppl, S. (2016). Articulation of work process models for organizational alignment and informed information system design. Information & Management, 53(5), 591–608. http://doi.org/10.1016/j.im.2016.01.004". It has been modified to provide consecutive numbering of sections and figures throughout this thesis.

methodological knowledge about modeling (Recker et al. 2012). Their role in traditional IS-oriented modeling approaches is thus widely reduced to providers of domain knowledge for expert modelers (Santoro et al. 2000). An expert-mediated approach of representing work process knowledge in conceptual models bears the risk of introducing the expert modeler's own bias regarding which information should be represented in the model and the interpretation of vague or conflicting statements provided by the actors (Goncalves et al. 2009). This not only negatively affects actors' ability to interpret the information represented in a model (Joosten 2000) but also leaves unresolved potential misconceptions or conflicting understanding of work among the involved actors (Herrmann et al. 2002; Prilla & Nolte 2012). *The aim of the present work is to introduce a model elicitation approach, which is driven by actors and allows them to articulate and align their views on a work process, and still leads to a syntactically correct and semantically sound process model for further processing in IS.*

From a practical perspective, organizations would benefit from such an approach as it supports operative staff to align conflicting understandings and resolve misconceptions about their work. This reduces the effects of unforeseen contingencies (Strauss 1993) and allows to identify potential for improvement in the overall work process (Fjuk & Dirckinck-Holmfeld 1997). As the work process usually is shaped and supported by information systems, these aligned views should be reflected in the models used to design these systems in order to appropriately support the work process (Mullery 1979).

Involving actors in modeling activities has been addressed in several fields of research. In the field of system dynamics, approaches such as those of Vennix et al. (1996) or Franco & Rouwette (2011) focus on involving actors and resolving conflicting viewpoints as noted above. The resulting models, however, are not intended for the development of socio-technical support in IS. Research in the area of business process modeling shows that established formal modeling languages such as BPMN (Business Process Modeling and Notation) (White & Miers 2008) are used for modeling driven by actors (e.g. (Luebbe & Weske 2011)), but lead to the sacrifice of formal correctness and semantic completeness for usability (Recker 2010), which makes them of limited use for further processing. A third strain of research in the area of socio-technical system design focuses on collaboratively capturing information about work processes from actors by providing notations explicitly tailored for understandability and easy use (e.g., (Herrmann et al. 2007; Hoppenbrouwers et al. 2013; Antunes et al. 2013)) while still maintaining a link towards technical interpretability of the created models. The task of transforming these models to representations that can be processed in IS, however, is left to expert modelers (e.g. (Santoro et al. 2010)). (Margaria et al. 2013) argue in favor of a simple modeling approach that allows actors to create directly executable role-based workflow models and present a framework on how this aim can be achieved with modeling support tools. Fahland & Weidlich (2010) and Kabicher & Rinderle-Ma (2011) argue in favor of approaching actors with a case- or scenario-based approach to modeling, respectively, in which elicitation focused on capturing case-based process fragments, which are later (semi-)automatically aggregated to form a complete model of the process.

All of the above-mentioned approaches aim at facilitating work modeling by actors without formal process modeling experiences. They either focus on supporting actors' needs in a collaborative modeling process or aim at producing executable models that can be processed directly in IS. The challenges addressed in both areas are of high relevance for the aim of involving actors in IS design but have not yet been addressed in an integrated approach. *The present work addresses this issue and introduces a methodology to facilitate actors' collaborative articulating of their work processes. It furthermore presents a support tool for conflict resolution and model elaboration, leading to formally correct models that are necessary for technical processing in IS.*

Collaborative articulation of work process models should lead to common ground (Clark & Brennan 1991) for all involved actors and serve as an agreed-upon basis for further use. This is necessary, because actors' mental models of how they contribute to a work process and how they interact with each other can be assumed to be inconsistent (Strauss 1993). This eventually leads to problems in collaboration (Vennix et al. 1996). Existing work on collaborative conceptual modeling hardly addresses explicitly the differences in how people perceive collaborative work processes (Renger et al. 2008). Also, no account is given on how to resolve these differences to an extent that allows reaching common ground on how to collaborate (Rouwette et al. 2002). *The methodology presented in this chapter contributes to this area of research by introducing a modeling method that makes visible differences in understanding and requires resolving them to be able to finish the modeling process.*

The present work methodologically follows a design science approach (Hevner et al. 2004). The modeling approach and the proposed tools are to be considered the *designed artifacts*. Although involving operatively active people in the work process modeling for the sake of IS design has been recognized as a relevant field of study, the *rationale* of the present work is that no approach so far has addressed how to support the process of articulating and aligning potentially conflicting views on work processes while still maintaining a model representation that can be directly processed in IS. The *contribution* of the present work is a methodology that enables non-expert modelers to collaboratively create conceptual models of a shared work process by articulating and aligning their individual views on the work process. The resulting models are technically interpretable in IS. The methodology is supported by a set of tools that facilitate articulation, alignment, and conceptual modeling to achieve these ends. *Research rigor* is ensured by deriving the designed artifacts' requirements from the relevant literature in the fields of articulation support in collaborative settings and conceptual modeling support for inexperienced modelers. This brings together the research domains that are relevant for this work as described in the design rationale. The artifact design process solely is based upon these requirements. Consequently, *evaluation* in the present work focuses on assessing whether these requirements have been met. A case study has been conducted to evaluate the designed artifacts in the intended field of application, and to identify the potential advantages and areas of improvement for the results presented here.

The remainder of this chapter is structured as follows. In Section 3.3.2, we elaborate on the question of *how conceptual modeling can be adopted for articulation support*. In Section 3.3.3, the methodology designed to meet these requirements is introduced and described in detail. A brief description of the tools that have been developed to support the different methodological phases closes Section 3.3.3. In Section 3.3.4, the case study used to examine *if the proposed modeling approach meets the identified requirements* is presented. The chapter concludes with an account of the limitations of the presented research and discusses the potential for further methodological and technical developments.

3.2 Conceptual modeling for articulation support

Representing the procedural aspects of work in conceptual models is one prerequisite for informed IS design (Curtis et al. 1992). Commonly adopted modeling languages such as BPMN (White & Miers 2008) or EPC (Event-driven Process Chain) (Nüttgens & Rump 2002) provide constructs to describe the activities that constitute a work process and their causal relationships. Most of these modeling languages aim at representing models for further processing by means of technology (such as simulation or workflow execution; see (Curtis et al. 1992)). Conceptualizing work in a technically interpretable manner, however, is not always feasible when capturing information about work processes from inexperienced modelers. People's mental models about their work processes are likely to be incomplete and inconsistent (Seel 2003). When using a modeling language oriented towards technical interpretability (Krogstie et al. 2006), its semantically exact specified constructs might be too limiting to fully capture the information that people articulate based on their mental models (Falkenberg et al. 1998).

This challenge has been recognized for years in the area of socio-technical systems design (Herrmann et al. 2002). One approach to overcome modeling constraints imposed by model semantics is to explicitly allow for vagueness in the models, deliberately leaving aside information that is incomplete or inconsistent at the time of modeling. This approach is implemented in modeling languages such as SeeMe (Herrmann et al. 2000), which explicitly introduces a construct to express vagueness, but also BPMN (White & Miers 2008), which allows the use of a reduced set of model constructs with relaxed semantics when creating models with the involvement of inexperienced modelers (ibid.). This approach allows models that are syntactically correct and do not contain any semantically incorrect information to be quickly captured. However, it potentially omits information that is considered inconsistent or non-consensual in the modeling situation.

The approach presented in this work explicitly targets such inconsistencies and focuses on their resolution in the course of modeling. Information is provided by the actors and directly represented by them in the model. They follow a multi-step approach through the modeling process, which is described in the following. Modeling is initially carried out on an individual level to collect individual viewpoints on the work process followed by a collaborative consolidation phase and subsequent elaboration of the resulting model. It then can be interpreted and processed further in IS.

3.2.1 Requirements

Collaborative modeling is the goal-driven joint effort of several people in order to create a representation of those parts of the real world they consider relevant for the modeling goal (referred to as "topic of modeling" in the following - cf. model theory of Stachowiak (1973)). Collaborative modeling is successful if every involved person considers the model to depict appropriately her/his perception of the topic of modeling (Krogstie et al. 2006) and considers the model to be useful with regard to the modeling goal (ibid.).

In collaborative modeling, the topic of modeling is a collaborative work process. The goal of the present research is to enable the articulation of a collaborative work process by the people operatively involved in it ("actors"). Consequently, actors are the participants of a collaborative modeling session. Everybody involved in a collaborative work process contributes to the overall aim by performing activities guided by individual mental models of the work process (Seel 2003). The mental model of an operatively inexperienced actor is refined only to the extent that it allows the next activities to be chosen based on the perceptions of the work situation (Ifenthaler et al. 2007). Performing work based on such incomplete mental models might lead to problems in work situations where two or more people need to collaborate and therefore need to have a shared understanding of how to appropriately perform activities as a group. Although mental models are refined over time with rising experience, unobservable contributions of others cannot be incorporated in one's mental model. Limiting one's mental models to individual contribution prevents identification of the potential for improvement, which could be gained by extending collaboration beyond the currently established way of working.

Thus, the goal of a collaborative modeling session aiming at improving a collaborative work process is to facilitate common ground of the work process as a whole and the collaborative aspects in particular. "Common ground" is reached when the actors "mutually believe that the partners have understood what the contributor meant to a criterion sufficient for current purposes" (Clark & Brennan 1991)(p. 129). It can be facilitated by providing a communication setting ("medium"), in which all contributors can articulate how they perceive their work and can negotiate the aspects that are not agreed upon in an argumentative way (Rittgen 2009a; Türetken & Demirörs 2011). Such grounding activities are more likely to be necessary in the collaborative aspects of the work process than in those parts that a single contributor performs autonomously (Türetken & Demirörs 2011).

A modeling approach that serves the given goal thus needs to lead to a comprehensive representation of the overall work process. It needs to take into account all individual contributions and facilitate identifying and making visible different mental models of how the collaborative aspects are performed (Mullery 1979). The requirements on articulation support (AR) of such an approach are derived in the following and are based on existing literature.

3.2.1.1 Articulation Requirement 1

In order to be able to identify different perceptions of how collaborative work is carried out, the individual mental models of the collaborating contributors need to be made accessible for alignment (Engelmann & Hesse 2010; Novak & Canas 2006). Externalization of mental models (i.e., creating explicit representations of mental models) is a recognized means to serve this purpose. Conceptual models are a form of representation that has been shown to be suitable for mental model externalization (Ifenthaler et al. 2007). The act of representation leads to elaboration of the mental model of the externalizing individual, creating a result that serves as an artifact for making the mental model understandable for others (Dann 1992; Rittgen 2007; Türetken & Demirörs 2011). Consequently, a collaborative modeling approach to work should profit from a phase during which the participants individually externalize their mental model of the work process in the form of a conceptual model (*AR 1*).

3.2.1.2 Articulation Requirement 2

A common vocabulary used by all involved participants to describe their mental models is a prerequisite for alignment on content level (Sarini & Simone 2002; Roschelle 1996). The existence of common ground here cannot be taken for granted, particularly when people with a diverse professional background are involved (Sarini & Simone 2002). The relationship between the vocabulary used to describe concepts in the real world and the actual real world phenomena is not unique, since different notions can be used by different people to refer to the same concept (Roschelle 1996; Weinberger et al. 2007). Explicitly aligning the notions used to describe the aspects of a work process in a model therefore contributes to creating common ground (F. Fischer & Mandl 2005) (*AR 2*).

3.2.1.3 Articulation Requirement 3

Furthermore, the scope of the work process might not be obvious for all participants or even might be perceived differently by the participants (Weinberger et al. 2007). Facilitating a convergence of the understandings of the scope of the work (e.g., what triggers the start of the work process and how its end is recognized) and how the work environment is set up (e.g., identifying the relevant actors, necessary infrastructure, utilized resources, location of the process and/or its parts, etc.) is necessary before externalizing the individual contributions to the work model (*AR 3*).

The modeling approach to be developed here thus should facilitate the following activities: (1) creating individual models of the work process before creating a common model, (2) agreeing on a common description of the work process elements, and (3) creating common ground about the scope of the work process.

3.2.1.4 Articulation Requirement 4

The results of these activities provide a foundation for reaching common ground about the work process. This can be facilitated by conceptual models that serve as a shared artifact (F. Fischer & Mandl 2005). Weinberger et al. (2007) show that common ground develops through argumentative alignment of individual claims made by the participating actors. A conceptual modeling approach supporting this process should allow for the expression of individual claims and place them in the context of other claims for reviewability in the argumentative chain. This allows conflicting claims to be expressed and monitored, which is important since they need to be resolved in order to ultimately create a commonly agreed upon model (*AR 4*).

Approaches toward collaborative work modeling have already been discussed in the introduction. This prior research has identified additional supportive factors that have to be taken into account when designing a collaborative modeling method to support articulation and alignment. These modeling support factors (MSF) are described in the following.

3.2.1.5 Modeling Support Factor 1

Much existing research on collaborative modeling targets inexperienced modelers. Requirements originating from this target group are relevant for the present research, as operative work staff cannot be expected to have modeling experiences. Research on facilitating lay modeling focuses on measures to guide inexperienced modelers through the process of creating a model without overwhelming them with syntactic formalism and complex modeling constructs. Existing research (e.g., (Santoro et al. 2010; Fahland & Weidlich 2010; Kabicher & Rinderle-Ma 2011; Lai et al. 2014)) suggests that starting modeling based upon a concrete work case makes it easier for inexperienced modelers to develop an understanding of the necessary concepts to describe a work process in an abstract conceptual model (*MSF 1*).

3.2.1.6 Modeling Support Factor 2

Using a case-based approach to modeling also reduces the number of language elements necessary to depict the work process. For example, case-based models do not require decision constructs or elements for exception handling. While the number of modeling elements alone appears not to have a notable impact on the understanding of a modeling language for inexperienced modelers (Recker & Dreiling 2007), empirical evidence shows that the number of elements actually used during modeling is limited and highly dependent on the modeling objective (Muehlen & Recker 2008). When involving inexperienced modelers, it seems to be appropriate to limit the number of available modeling elements a priori to those appropriate for the intended modeling perspective and targeted outcome (Genon et al. 2011; Britton & S. Jones 1999) (*MSF 2*). In the present case, the modeling perspective is oriented towards the work of actors and their interactions within an organization. The targeted outcome is reaching common ground on the work process for non-expert modelers.

3.2.1.7 Modeling Support Factors 3 and 4

Furthermore, Herrmann & Nolte (2014) and Santoro et al. (2010) provide evidence that non-formalized information and annotations to model elements can aid the externalization process. However, they do not force the modelers to express all information using the constructs of the modeling language (*MSF 3*). Some results also point at the importance of (human or automatic) facilitation and scaffolding during the model creation process (Hjalmarsson et al. 2015) and the model alignment process (Rittgen 2007), particularly for inexperienced modelers (Davies et al. 2006) (*MSF 4*). Current research indicates that procedural and structural scaffolds provided by a facilitator or an automated system may support the elaboration of incomplete models (Herrmann & Loser 2013; Hoppenbrouwers et al. 2013). The effectiveness of these approaches, however, still needs to be validated empirically.

3.2.1.8 Summary

Summarizing, the following properties of a modeling approach support collaborative modeling by inexperienced modelers: (1) starting with case-based development of process models, (2) offering a constrained set of modeling constructs with semantics focused on the modeling objective, (3) enabling informal annotations of model elements (i.e. not adhering to formal modeling syntax), and (4) offering procedural and structural scaffolds for model creation and alignment.

Figure 3.1 shows the articulation requirements (ARs) and modeling support factors (MSFs) derived above. Implementing ARs 1 and 2 is at the core of supporting the transition from potentially divergent individual mental models about work to a commonly agreed-upon externalized representation of a work process that provides a sound foundation for IS design. ARs 3 and 4 support this transition by clarifying the scope of work and keeping track of the articulation and alignment process, respectively. The implementation of the ARs by means of conceptual modeling is facilitated if MSFs 1-4 are considered during method design. MSFs 1 and 2 are relevant in particular for implementing AR 3, whereas MSFs 3 and 4 enable the implementation of AR 4. All four MSFs are finally relevant for ARs 1 and 2, as will be described in Section 3.3.3.

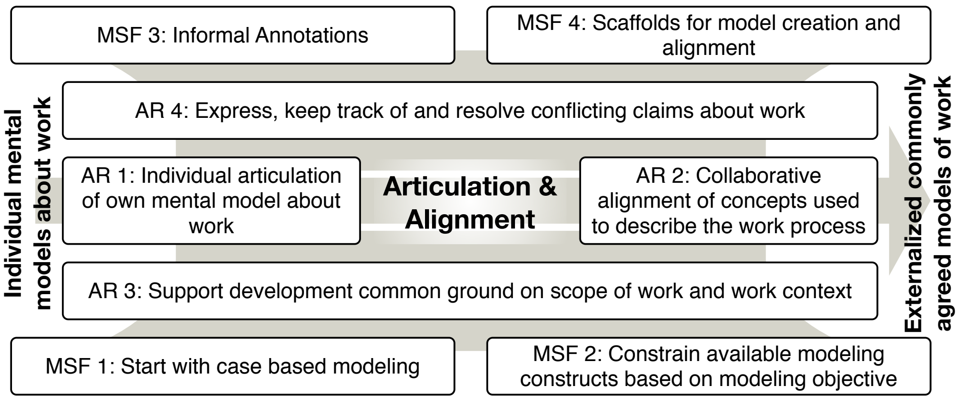

Figure 3.1: Articulation requirements and modeling support factors

3.2.2 Modeling Language

Models of work processes that should express the collaborative aspects of work need to provide semantic constructs to represent who is involved in the work process, which activities are performed by the involved entities, and what information or artifacts are exchanged by them. These elements describe the coordinative aspects as well as the operative aspects of work and thus can be considered the minimal set of conceptual elements necessary to describe collaborative work (Fjuk & Dirckinck-Holmfeld 1997). This assumption has been backed by the development of business process modeling languages over the last few years, where the focus has shifted from functional approaches (e.g., EPCs; (Nüttgens & Rump 2002)) to approaches that structure process descriptions along the involved entities and explicitly allow them to express their interaction (e.g., BPMN (White & Miers 2008) or S-BPM (Fleischmann et al. 2012)).

The mentioned interaction-oriented modeling languages are designed to describe complex business processes, covering all their variants and potential exceptions. The modeling constructs introduced to handle this complexity, however, are not required for the articulation approach proposed here. Starting articulation with a case-based narrative approach (MSF 1) avoids the need for control flow constructs beyond describing sequences of activities and interaction with others. This reduces the number of modeling elements (MSF 2) to make modeling easier for non-expert modelers. Based on empirical data collected on practicioners' use of BPMN 2.0, zur Muehlen & Recker (2008) show that for interaction-oriented modeling for organizational work processes, at most the following constructs are used: *Task* and *sequence flow* to indicate what is to be done in which sequence, *pools* to indicate who is doing what, *message flows* to couple the process parts in the pools, and *events* indicating the *start* and *end* of the process. Abstracting from BPMN notation, the modeling language proposed here consequently consists of the following three modeling elements: WHO–element: representing actors, roles, or organizational entities (exact semantics depending on the level of abstraction individually chosen for modeling - cf. MSF 2) ("pools"); WHAT–element: representing activities ("tasks"); and EXCHANGE-element: describing exchange of information or artifacts among WHO-elements (exact semantics depending on designator for element - cf. MSF 3) ("message flow")

These elements are put into mutual relationship by spatially arranging them as follows: Each WHAT-element is assigned to a WHO-element by placing it on an imaginative straight line originating from the WHO-element (assignment of "tasks" to "pools"). Causality between WHAT-elements is expressed by their order on the line starting with the one that is placed nearest to the WHO-element ("sequence flow," "start event," "end event"). EXCHANGE-elements are placed between the lines of the communicating WHO-elements and are causally related in the stream of WHAT-elements by spatial arrangement, explicitly adding connecting arrows from the activity in which or after which the exchange is triggered and to the activity that receives or is triggered by the exchange ("message flow")

As shown above, the proposed language covers the elements used for interaction-oriented modeling for organizational work processes as identified by zur Muehlen & Recker (2008) and can be mapped to formal business process modeling languages such as BPMN. The number of elements has to be reduced and assigned clearly distinguishable semantics in order to meet the articulation needs of inexperienced modelers (Genon et al. 2011).

3.3 Articulation support

The proposed modeling procedure comprises of three phases to address the ARs described above. The phases comprise multiple steps that are shown in Figure 3.2. The articulation process starts with a "setting-the-stage" phase, in which a concept map of the work context is created collaboratively. This is to achieve a common understanding of the relevant concepts and the scope of the process. This concept map serves as a peripheral artifact during the following phases, acting as a point of reference whenever ambiguities arise.

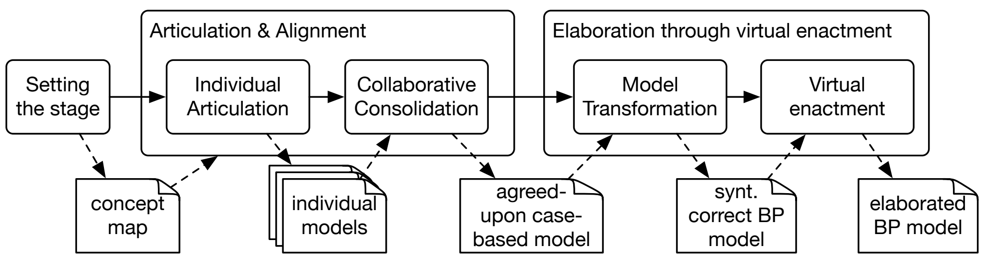

Figure 3.2: Articulation process steps and generated artifacts

"Articulation and alignment" of the work process starts with a set of concurrent individual articulation sessions, in which all participants create models of their work contributions and interactions with others. Individual articulation is followed by collaborative consolidation, in which the individual models are brought together and aligned to form a coherent and agreed upon model of the overall work process. Both individual articulation and collaborative consolidation are designed to facilitate the creation of case-based models (cf. MSF 1). The "articulation and alignment" phase can optionally be instantiated sequentially for different cases to provide a more comprehensive foundation for the next phase.

The case-based model serves as the foundation for the "elaboration through virtual enactment" phase, during which the model is revisited by going through the articulated process step-by-step and altering or extending the model whenever it represents the real work process in an incorrect or incomplete way. This step can optionally be repeated several times to thoroughly validate the model. Virtual enactment requires IT-support. The articulated case-based model thus needs to be transformed in a computer-interpretable model that can be loaded by the business process management system (BPMS) used for virtual enactment. If transformation fails due to missing or ambiguous model information, interactive resolution of these issues is supported. The result of virtual enactment is an elaborated and validated model of the work process, which then can be processed further during IS design. Further validation can be achieved by involving non-operative stakeholders in the consolidation and elaboration phases. They can contribute their perspectives on the work process and so add aspects that might not have been visible initially to the actors involved in individual articulation.

In the following, the steps of the process are described in more detail, including information on technical tool support for model transformation and elaboration through virtual enactment in the final subsection. A simplified organizational work process of an employee applying for a vacation is used for illustrative purposes consistently across all stages. It is distributed across three organizational roles: the employee applying for vacation, the secretary processing the application, and the manager deciding upon the outcome.

3.3.1 Setting the stage

Not all involved contributors necessarily have a common understanding of the concepts used to describe the different aspects of the collaborative work process (i.e. the WHO, WHAT, and EXCHANGE aspects) and the organizational setting in which the process is embedded (Sarini & Simone 2002) (AR 3). In an effort to "set the stage" for creating the collaborative work model, the modeling approach presented here incorporates a phase that aims at reaching common ground on the scope of the work process and concepts to be used for describing its relevant aspects.

The modeling method used for setting the stage is based upon research on collaborative concept mapping as a means to create common ground (van Boxtel et al. 2002;

Gao et al. 2007). Concept mapping is a method for externalizing and reflecting upon real world phenomena, which in turn reflects the cognitive structures of the creator (Feltham 2008).

Concept maps allow arbitrary model element types, which prevent misrepresentation or loss of information about individual work perceptions due to a lack of support regarding what people want to express (Sarini & Simone 2002). Creating concept maps without any semantic restrictions supports actors not used to thinking about distinct concepts and helps them to verbalize their work perception. Further, it guides them toward conceptual thinking and sets a common frame of reference for all members of the group. This frame of reference supports a consolidation of the different individual views on collaboration later on.

The actors are asked to describe their work environment by collecting items they consider relevant in the context of their work. Concepts are related by two means: spatial clustering of items and explicit associations by connecting two items and naming the connection. The aim of this initial phase is to make explicit the notions participants use to refer to their work and the perceived relationships among the concept considered relevant. This provokes discursive clarification of the scope of the work process and avoids fundamental misunderstandings in the subsequent phases, in which the work process itself is described.

3.3.2 Individual Articulation

The modeling approach has to comprise a phase where models of the actors' own perceived work contributions are articulated individually (AR1). These models then can be consolidated in a common model in a third phase (AR2). Individual modeling and the ability to consolidate to a common model are thus inherent properties of the proposed modeling approach. Models are structured along the entities that are involved in collaborative work. Therefore, actors can independently of each other describe (1) WHAT they do to contribute to the work process (their own activities), and (2) with WHOM they EXCHANGE information or artifacts (the actors or organizational entities they are interacting with and how this interaction manifests in information or artifact exchange).

The following spatial layout is used for the different elements to create a consistent form of model representation:

- WHO-items are placed on the upper border of the modeling surface, and indicate the role represented by the actor and those roles with which the modeler is perceived to interact directly.
- WHAT-items are placed below the WHO-item representing the role of the actor, and describe the actor's own activities. Their sequence indicates causal and/or temporal relationship.

- EXCHANGE-items are placed below the WHO-items of the other roles. They indicate expected exchange of information or artifacts. Their spatial arrangement indicates the causal and/or temporal relationship to the stream of WHAT-items:
  - EXCHANGE-items placed slightly above a WHAT-item indicate expected incoming information or artifacts. In case of ambiguity, this relationship can be made explicit by drawing an arrow connecting the EXCHANGE-item with the WHAT item requiring this input.
  - EXCHANGE-items placed slightly below a WHAT-item indicate offered outgoing information or artifacts. In case of ambiguity, this relationship can be made explicit by drawing an arrow connecting the WHAT-item producing this output with the EXCHANGE-item.

Figure 3.3 shows the three individually articulated models for the sample process. WHO-items are represented in blue, WHAT-items are red, and EXCHANGE-items are yellow. As an example, the model of actor 2 is described in narrative form in the following: the *secretary* perceives that he has to interact with his *colleague* and his *boss* to complete his role in the process. He expects to receive a *completed application* from the *colleague* to be able to start his contribution. He *checks for conflicts* with other submitted or already confirmed applications. The *checked application* is then forwarded to the *boss*. The secretary proceeds, as soon as he receives the *confirmed application* back from the *boss*. He then *files the application* and forwards the *confirmation* to his *colleague*.

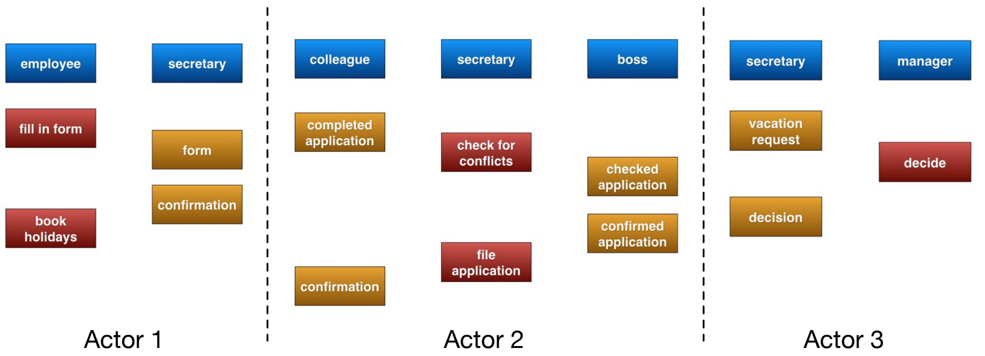

Figure 3.3: Sample result of individual articulation

Figure 3.3 also shows semantic differences between the models on the level of WHO-elements (e.g., "boss" vs. "manager") and on the level of EXCHANGE-elements (e.g., "form" vs. "completed application" or "decision" vs. "confirmed application"). These differences reflect different perceptions of the work process. They are addressed in the next phase, where the individual models are consolidated into a commonly agreed-upon model.

3.3.3 Collaborative Consolidation

Consolidation has to explicitly make visible and keep track of different perceptions of how to implement the collaborative work process (AR4). The individual models are thus merged and aligned according to the following scheme for consolidation in the phase of collaborative consolidation:

- One of the actors starts by placing the WHO-items on the upper border of the shared modeling surface. The actor responsible for starting the real-world work process (if known a priori) consequently should start modeling.
- The same actor continues by describing their own contribution to the work process by placing WHAT-items below their own WHO-item. Others do not intervene during this stage.
- As soon as the actor encounters the first EXCHANGE- or shared WHAT-item, the targeted communication partner (acting as the source or the sink of the exchange) steps in and starts by matching their own perception of the work process with the already externalized model. The following cases can occur here:
  - A matching EXCHANGE-item exists (i.e. an expected exchange that matches an offered exchange, or vice versa). In this case, the matching elements are merged and modeling continues.
  - There is no WHO-item for the original communication partner available (i.e. the partner has not perceived any collaboration with the original actor at all). In this case, a fundamental difference in work perception has been identified, which needs to be resolved by the participants.
  - There is no matching EXCHANGE-item available (i.e. the perception of collaboration was not shared or not considered relevant). In this case, a difference in work perception has been identified, which needs to be resolved by the participants.
  - A matching EXCHANGE-items exists, but is perceived to represent content or nature that is different from the exchanged information or artifact (i.e. share the perception of the need for collaboration but do not share a common ground on how it is implemented, or alternatively choose different levels of granularity to describe exchanges). In this case, a difference in collaboration perception has been identified, which needs to be resolved by the participants.
- If a match has been identified or different understandings have been resolved to ultimately form a match, the modeler responsible for the targeted entity continues to complete the model with the elements describing how he/she contributed to the work process until the agreed upon point of collaboration (i.e. the EXCHANGE element). This includes adding their own WHO elements.
- Consolidation continues in this way until all points of collaboration are agreed upon. If one actor has completed his or her contribution, others with remaining elements not yet incorporated in the common model take over and provide further

input to the consolidation process. If missing elements are discovered by an actor during consolidation, they are added by the responsible actor immediately, even if they had not been created during individual articulation.

- Any elements created during individual articulation which are not part of the collaborative model after the former steps (e.g., because they are considered irrelevant now by the contributing actor) need to be revisited explicitly and discussed in the group regarding their potential to be integrated in the model.

Figure 3.4 shows the consolidated model for the sample process. The matching WHO- and EXCHANGE-items are placed on top of each other. The final model now depicts the vacation application process in case of no conflicts identified by the secretary and a confirmation by the manager. The semantic differences existing in the individual models have been resolved in the agreed-upon model. The resolution is an integral part of the consolidation process carried out in this phase.

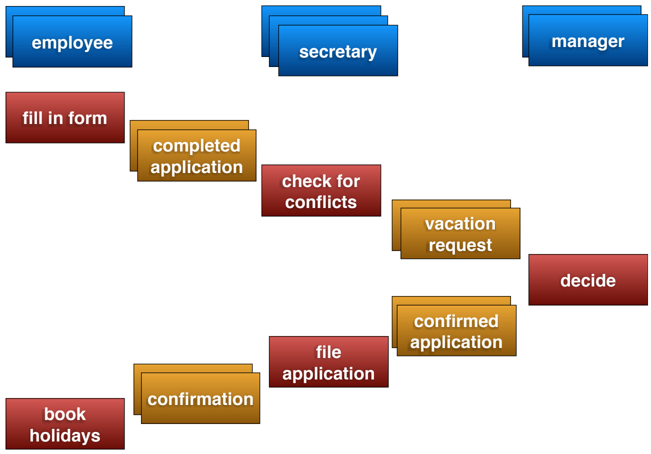

Figure 3.4: Result of collaborative consolidation

The whole process of consolidation aims at facilitating the creation of common ground on the collaborative work process. The matching of WHO- and EXCHANGE-elements, where mismatches in the individual models are explicitly made visible, triggers explicit alignment activities (AR 4). The involved people need to refine or alter their mental models to converge to an extent that allows reaching common ground on how to collaborate (Roschelle 1996).

Building upon Clark & Brennan's (1991) notions of “common ground” and “consensus,” Weinberger et al. (2007) describe which behavior to expect from people involved in these processes and list the following resolution strategies to deal with views that do not match.

Quick consensus building occurs when participants accept the contributions of others not because they are convinced, but in order to be able to continue discussion. This is non-desirable behavior in the above-mentioned cases that requires explicit resolution.

It is, however, acceptable when models created on different levels of granularity are matched (i.e., one model being more detailed than the other while not representing different perceptions of the actual work process) or only different naming has been used to describe the same concept (e.g., for WHO-elements "boss" and "manager" in the sample process depicted in Figure 3.3).

Integration-oriented consensus building is characterized by an adoption of the perspectives of other participants. Individuals may give up or modify their viewpoints and eventually their models on the basis of others' contributions. This behavior is to be expected in case of necessary clarification of the specific form or content of EXCHANGE-items. In the sample process, the EXCHANGE-items "form" (offered by actor 1) and "completed application" (expected by actor 2) represent such a case, where actor 2 has more specific expectations on the exchanged information than actor 1, while their fundamental intentions do not differ.

Conflict-oriented consensus building requires participants to face critique of their own models and views. They need to assess multiple perspectives to find better arguments for their positions. Creating consensus in a conflict-oriented manner requires participants to identify the specific conflicting aspects of the others' contributions. This might also be desirable behavior, as an understanding of other people's viewpoints is required to present acceptable alternatives. The models in this case act as externalized artifacts of those viewpoints, which ease the process of understanding and facilitate the making of proposals (Hornecker 2002). In the sample case, this could be triggered by the EXCHANGE-items "decision" offered by actor 3 and the "confirmed application" expected by actor 2. Those items are of fundamentally different nature, as "decision" implies an open-ended outcome, while "confirmed application" points to an expected positive decision. In the process leading to the model in Figure 3.4, the conflict could have been resolved if actor 3 agreed to remain with the case of a positive decision for the initial agreed-upon model and come back to the other variants in the next phase, where the process is elaborated through virtual enactment.

The model evolution supports reaching common ground as the current state of the model continuously serves as a shared artifact for reviewability and clarification purposes (F. Fischer et al. 2002; van Boxtel & Veerman 2001). The immediate visibility of fundamentally different viewpoints in the model should prevent a quick consensus building where necessary and requires actors to use more elaborate strategies like integration- or conflict-oriented consensus building. After reaching common ground and reflecting upon changes in the model, it represents an agreed upon representation of the respective parts of the collaborative work.

3.3.4 Elaboration through virtual enactment

Completing the modeling phases described so far leads to models that are semantically incomplete representations of a work process. Most notably, these models do not account for different variants of a work process that are represented using decision elements in other business process modeling languages (e.g., in the sample process, negative outcomes are not yet represented). The present work deliberately follows a case-based approach to reduce model complexity for the targeted inexperienced modelers (cf. MSF 1). A comprehensive model of the business process, however, is still required for further processing during IS design. For this reason, the case-based models are elaborated interactively using process enactment tools, which play through the work process step-by-step and alter and extend the model whenever the enactment is incorrect or incomplete with regard to the perceived real-world work process. It should be stressed at this point that participants during the virtual enactment do not perform modeling. At this stage, they interact with a BPMS implemented for this purpose within our research (Kannengiesser et al. 2014). This BPMS presents web-based dialogue forms to the participants, allowing them to describe the deviations from the currently enacted process. The BPMS supports the description of the new or altered process steps by providing the current process context (i.e., what was done, before the deviation was started), as well as information about potential interaction partners.

Completing collaborative alignment leads to models that are transformable to models created with role-centric, communication-oriented business process modeling languages such as S-BPM (Fleischmann et al. 2012) or BPMN (White & Miers 2008). The mapping from the case-based model to the target business process model fully represents the structure of the case-based model in the target model. By applying a set of transformation rules, a source model adhering to the layout rules described above can be mapped to a syntactically correct target business process model. Syntactic correctness enables further processing of the model and uses it for execution in a BPMS as described above. Elaboration during execution requires altering the model while an instance of it is currently being executed. This is not a common feature of BPMS. For the present research, a system processing S-BPM models has been extended to provide this functionality within our research (Kannengiesser et al. 2014), which is described in more detail in Section 3.3.6. While not being a part of the methodology, S-BPM offers close conceptual similarity to the modeling language introduced for the first part of the methodology. A subset of BPMN, being the source for language design in Section 3.2.2, conceptually would also be a valid choice, but has not yet been examined more closely in our current research due to limited engineering resources. The following descriptions focus on S-BPM but are equally applicable to BPMS based on other languages.

3.3.4.1 Transformation

S-BPM models consist of behavioral models, which describe the activities (“action states”) and communication acts (“send state” and “receive state”) of each role involved in a process. These behavioral models are encapsulated in “subjects,” with each representing one process role and used in an interaction model, which provides a bird’s-eye view on the communication happening among subjects in the process. The WHO-items of the source-model are mapped to “subjects,” the WHAT-items are mapped to “action-states," and the EXCHANGE-elements are transformed to corresponding "send-" and "receive-states." The detailed transformation and mapping process is beyond the scope of this chapter. It is described in detail by (Oppl 2015), who also addresses how to resolve issues that arise from incomplete source models or ambiguous source model layouts.

Figure 3.5 (left) shows the result of the transformation process for the sample model, depicting the interaction model and the behavioral diagrams of the subjects. The interaction diagram shows the subjects and messages exchanged between them and can be directly derived from the spatial arrangement of the WHO- and EXCHANGE-items in the consolidated model. The behavior diagrams show the activities and communication acts of the involved subjects. They are derived from the spatial arrangement of the WHAT-items assigned to the WHO-element representing the subjects and the incoming and outgoing EXCHANGE-items. Each outgoing EXCHANGE is mapped to a send-state and each incoming EXCHANGE is mapped to a receive-state, respectively.

3.3.4.2 Virtual Enactment

Models without syntactic errors can be directly used for virtual enactment in the BPMS. For this purpose, an instance of the process derived from the original model is started. As stated above, this model initially only reflects one single variant of the process, omitting more sophisticated control flow constructs such as decisions or loops. The aim of elaboration through virtual enactment is creating a semantically correct representation of the work process in all its variations as perceived by the involved actors.

The actors enact the process step by step. For each step the responsible actor assesses whether the step is correct and described in sufficient detail and whether the next step is the only possible way to progress or if there are alternative ways of continuing with the work process. This can refer to alternative options of progressing, optional activities or activities that have been omitted in the original model. The model is altered if any of these assessments lead to the need for changes in the process. The BPMS directly accesses the modified model representations and continues with the execution (cf. Section 3.3.6 for a more detailed description of tool support in these steps).

3.3.4.3 Refinement

Changes can have different effects that might trigger the need for further changes in the overall process. Potential changes in ascending order with respect to their impact on the overall process are described in the following. The nomenclature of the modeling language described in Section 3.2.4 is used for reasons of consistency: (1) adding, altering, or removing WHAT-items to a WHO-item, (2) shifting responsibilities for WHAT-items between WHO-items, (3) altering the sequence of EXCHANGE-items between WHO-items, (4) adding or removing EXCHANGE-items required from or provided to another WHO-items, and (5) involving a new WHO-items in the process.

Case 1 refers to situations where only the behavior of a WHO-item is altered without affecting its interfaces to other WHO-items. Content, form, and sequence of EXCHANGE-items remains unchanged. In this case, the changes only affect one WHO-item and do not require further changes. *Case 2* refers to situations where the content, form, and sequence of EXCHANGE-items remain unchanged but responsibilities are shifted from one WHO-item to another. In this case, the affected WHAT-items must be incorporated in the behavior of the target WHO-item. *Case 3* refers to situations where the sequence of EXCHANGE-items is altered but both content and form remain unchanged. In this case the WHO-item partnering in the communication needs to adapt its behavior to fit the new expectations. This might trigger subsequent changes for this WHO-item, which again potentially causes cascaded changes elsewhere in the process. *Case 4* refers to situations where the EXCHANGE-items are fundamentally altered in a way that adds or removes communication acts to or from the behavior of the involved WHO-items. This necessarily causes changes in the targeted WHO-item, as it needs to react to new information or provide information that was not expected before the change. This again potentially causes cascaded changes elsewhere in the process. *Case 5* finally refers to situations where a new WHO-item is added to the process. This requires specifying the communication interface (i.e. the EXCHANGE-items) with this new WHO-item as well as its WHAT-items, if they are known and relevant to the work process. Adding a new WHO-item might have implications on the behavior of the other involved WHO-item, as additional EXCHANGE-items might be required.

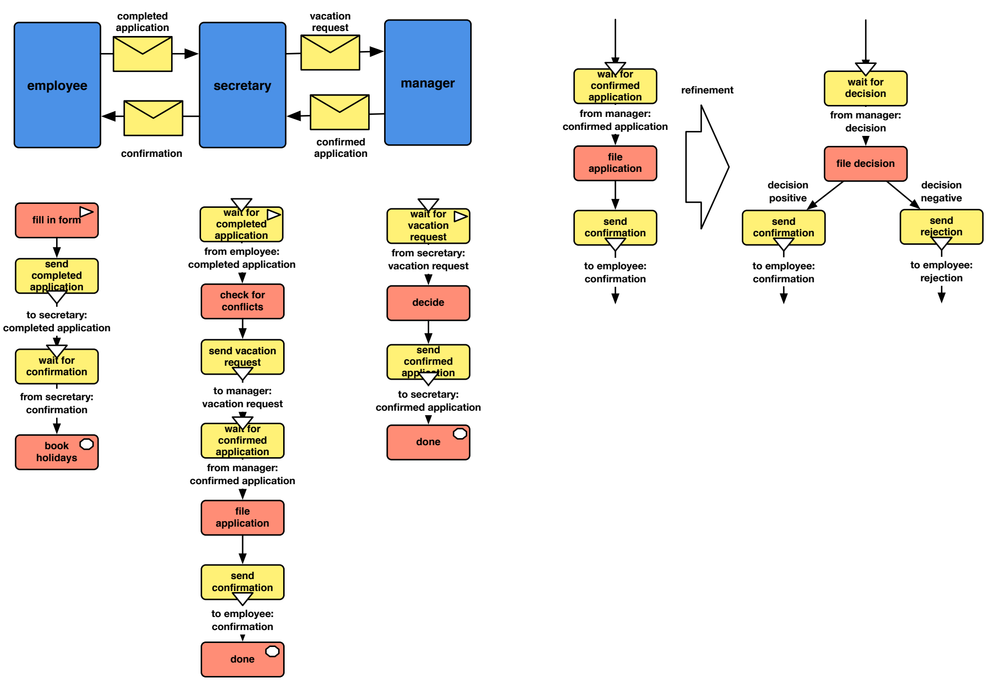

Figure 3.5: Result of model transformation (left), and result of elaboration through virtual enactment (right)

If a change to the model triggers the need for further changes (i.e., in cases 2-5), those cascaded changes do not necessarily need to be made immediately. The elaboration of the overall process, however, can only be finished if all open change requests have been resolved.

Figure 3.5 (right) shows an elaboration in the secretary's behavior, which reflects the potentially negative outcome of the decision of the manager. The shown elaboration has been triggered by a change in the manager's behavior, altering the message from "confirmed application" to "decision" (*case 4*). The change in the secretary's behavior is to assess the decision during filing and accordingly to communicate the different outcomes to the employee (*case 4*). Consequently, the employee also would have to adapt his or her behavior to reflect the altered incoming messages.

Elaboration through virtual enactment is a means to generate a process description without the need to manually create comprehensive formal process models by traditional conceptual modeling. Separation of models and model changes along the different involved subjects reduces complexity and allows a focus on one subject's behavior at a time. Using the execution engine allows complex decision processes to be modeled by incrementally adding process variants to the model as the enactment continues. Complex models of collaborative work processes are developed in this way without the need to ever translate one's perceptions of a work process to abstract process descriptions.

It is important to note that the resulting model not necessarily is complete or valid in terms of representing organizational reality. The completeness and objective validity of the resulting model is constrained by the limited views of the involved actors on the overall organization. Non-operatively involved internal or external stakeholders – due to their position – might be able to articulate further relevant aspects about the work process. Involving them in the consolidation and elaboration process or having them validate the results of either phase can address this issue, if a more comprehensive process representation is required from an organizational perspective.

3.3.5 Summary of methodology and comparison to related work

Table 3.1 summarizes the steps relevant for articulation and alignment. They are described regarding their actor involvement, the generated artifacts, and the addressed ARs and MSFs.

The identified ARs and MSFs provide the necessary framework to compare the presented approach with related work. Reviewing the existing literature for approaches that propose a methodology which uses conceptual modeling for collaborative articulation of work in order to produce models that serve the purpose of designing IS and that are empirically validated, suggests the following approaches for further analysis: Socio-Technical Walkthrough (STWT) (Herrmann et al. 2007), Collaborative Modeling Architecture (COMA) (Rittgen 2009b), and Plural (Türetken & Demirörs 2011). These approaches are discussed with respect to the ARs and MSFs.

Table 3.1: Summary of methodology

Phase	Interactive Step	Actor Involvement	Generated artifacts	Addressed AR & MSF
1	Setting the stage	collaborative	concept-map of work context	AR: 3 MSF: 2, 3
2	Individual articulation	n individuals	n individual models of perceived contribution to work	AR: 1 MSF: 1, 2, 4
	Collaborative consolidation	collaborative	agreed-upon model of overall work process, case-based	AR: 2, 4 MSF: 1, 2, 3,4
3	Elaboration through virtual enactment	collaborative	elaborated, executable model of work process	AR: 1, 2 MSF: 3, 4

3.3.5.1 3.5.1 Socio-Technical Walkthrough

STWT-Workshops (Herrmann et al. 2007) target domain experts who do not necessarily need to have modeling experience. The STWT uses SeeMe (Herrmann et al., 2000) as a modeling language, which comprises three core-modeling elements with context sensitive semantics (MSF2+) and is designed to represent models of socio-technical systems. It represents vague information, which explicitly captures disputed or unclear parts of a work process (AR4+). Informal annotations can be added to the model (MSF3+), and the resulting models are intended for use in IS design but are not executable in BPMS. The STWT does not explicitly collect individual work contributions in models but strives to consolidate divergent views through moderation techniques directly in the workshop setting (AR2+). No explicit scaffolds for model creation or alignment, however, are embedded in the methodology or the modeling language. Reaching a common understanding about the scope of work and the work environment is an integral part of the methodology (AR3+). The STWT is usually implemented as a series of workshops, allowing iterative elaboration of the model, but does not explicitly focus on case-based modeling (MSF1?).

3.3.5.2 Collaborative Modeling Architecture

COMA (Rittgen 2009b) focuses on providing support for articulating (->AR1+) and consolidating (AR2+) models during collaborative modeling with a language-agnostic negotiation approach. The COMA tool provides support for UML (Unified Modeling Language) and enables actors to communicate via the software in a structured way specified by the COMA methodology. Support of informal annotations is not mentioned (MSF3?). Following its negotiation-oriented approach, COMA does not make any explicit claims on whether clarifying the scope of the process is suggested as a dedicated activity (AR3?) or on whether model creation should start following a case-based approach (MSF1?). COMA does not explicitly address inexperienced modelers. It provides scaffolds for model consolidation (i.e., the negotiation process) (MSF4+). These scaffolds make explicit divergent views and suggestions for a common view, which is ultimately agreed upon with the support of a human facilitator (AR4+).

3.3.5.3 Plural

Plural (Türetken & Demirörs 2011) is a method based on a multi-perspective modeling paradigm (Mullery 1979), which focuses on representation of individual work contributions in models (AR1+) and subsequently merges them into a common model by agreeing on the interfaces among the individual models (AR2+). It uses eEPC (enhanced EPC) (Nüttgens & Rump 2002) as a modeling language and assumes that actors are familiar with this language. Plural uses tool support built upon a commercial modeling environment, which identifies inconsistencies between individual models (AR4+). Clarifying the scope of the work process is not explicitly mentioned to be a part of the method (AR3?). Informal annotations are supported as far as eEPCs can comprise them; they are not mentioned as a part of the method (MSF3?). The same holds true when following a case-based modeling approach (MSF1?). Türetken & Demirörs (2011) mention tool support for resolution of inconsistencies between models but do not elaborate further on how scaffolding is implemented (MSF4?).

3.3.5.4 Summary

Existing approaches to supporting collaborative articulation and modeling either target inexperienced modelers (such as the STWT+SeeMe) or aim at producing a formally correct model that can be directly processed in IS (such as COMA or Plural). This is a reasonable approach given the conflicting requirements in those areas (Zarwin et al. 2014). From an IS-design perspective, however, it remains desirable to satisfy requirements in both areas with a single methodological approach (Joosten 2000). Reviewing the results presented in Table 3.2, it appears to be possible to adapt the existing approaches to reach similar objectives as the proposed approach in its different phases. The present work still goes beyond the state-of-the-art by proposing a methodology that combines two modeling languages to transition from articulation-oriented modeling toward elaboration of formal models. To enable this transition, the formal modeling language used for the latter phase is syntactically and semantically compatible to the representation used for articulation and alignment support in the first phase. The necessary transition between representations affects the design of the support tools, which are described in the following.

Table 3.2: Comparison with related work ("+" indicates fulfilled criteria, "?" indicates ambivalence of the approach to the respective criterion, empty cells indicate not explicitly supported criteria)

	Targeted actors	**Resulting Model**	**AR 1**	**AR 2**	**AR 3**	**AR 4**	**MSF 1**	**MSF 2**	**MSF 3**	**MSF 4**
STWT+ SeeMe	Domain experts	SeeMe, not exec.		+	+	+	?	+	+	
COMA+ Tool	need to know UML	UML, executable	+	+	?	+	?		?	+
Plural	need to know EPCs	EPC, executable	+	+	?	+	?		?	?

3.3.6 Tool support

The modeling procedure described above requires technical support to enable transition between the articulation and elaboration phases. The tools designed to provide this support are described in the following. Phases 1 and 2 are methodologically based on collaborative conceptual modeling. Carrying out such collaborative conceptual modeling activities does not necessarily require support by IT-enabled tools and can benefit from tangible representation of the modeling elements (Dann 1992; Luebbe & Weske 2011). Phase 3, however, relies on IT to support elaboration through virtual enactment. Thus, a tool prototype has been designed that allows for tangible modeling of the work process and context in Phases 1 and 2. It allows (semi-)automatic transformation to a digital model representation that can be processed further in Phase 3.

3.3.6.1 (Semi-)automatic model transformation

Modeling Phases 1 and 2 is carried out using physical cards (cf. Figure 3.6), which are used to create models according to the structuring guidelines described in Sections 3.3.2 and 3.3.3. After finishing Phase 2, the resulting card-based model should represent an agreed upon perception of the collaborative work process. The card-based models need to be converted into digital model representations for further processing in Phase 3. Manual transformation is time-consuming and error-prone. An IT-supported tool has thus been developed to transform the card-based model to a digital model representation, which can directly be processed in a BPMS. The operative design goal for this tool is to avoid the need to split an articulation workshop into two parts because of the need for manual model transformation.

The bridge between the card-based model and the digital model is designed to work as transparently for the user as possible. User interaction should only be necessary if syntactical model information derived from the card-based model is ambivalent or incomplete and requires elaboration. The card-based model initially is captured as a pixel-based image in the first step via taking a picture, for example with a mobile phone. The modeling cards hold visual markers that can be recognized and uniquely identified in the picture (cf. Figure 3.6, first image).

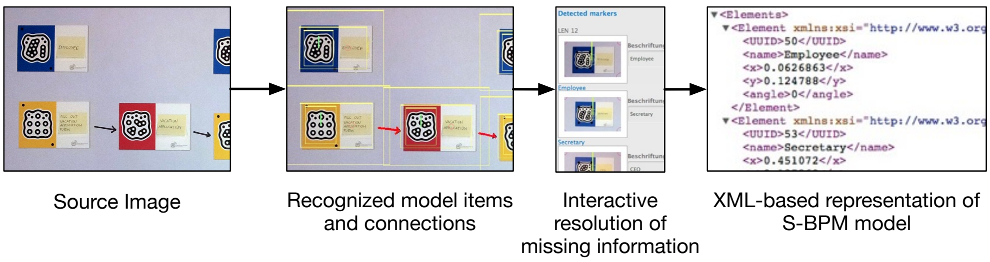

Figure 3.6: Transformation process from card-based model to formal S-BPM model

The optical marker recognition engine is based upon the ReacTIVision system (Kaltenbrunner & Bencina 2007) and identifies the coordinates of each marker. Based upon this information, the cards contained in the image can be identified and extracted (cf. Figure 3.6, yellow bounding boxes in second image). The extracted information is also used for identification of potential connections that are drawn between cards (cf. Figure 3.6, red arrows in second image). The model layout is analyzed in the next step regarding its adherence to the model layout rules described in Section 3.3.3. Those parts of the model that adhere to these rules can be transformed to S-BPM automatically and are stored as an XML-representation (cf. Figure 3.6, fourth image). If modeling rules are violated, missing, or ambiguous, then the information needed for the transformation can be added interactively (cf. Figure 3.6, third image). IT-based guidance through the interactive parts of the transformation process is currently implemented prototypically and described by (Oppl 2015). Once the transformation process is finished, the resulting model can be used for elaboration through virtual enactment.

3.3.6.2 Elaboration through virtual enactment

Elaboration through virtual enactment is performed using a BPMS that allows process descriptions to be altered during runtime. It is a means to generate a process description without the need to manually create comprehensive formal process models. Using the BPMS described by Kannengiesser et al. (2014), playing through complex decision processes is enabled by incrementally adding process variants to the model as virtual enactment continues. To avoid losing the context of the enacted work process (i.e., losing all entered data or information about earlier decisions), these model changes must not require a restart of the virtual enactment. The need to restart workflow execution in the case of model changes is a technical constraint of most currently available BPMS (Kannengiesser et al. 2014). The BPMS has been functionally extended as a prerequisite for the present research and supports deviations from a currently executed process model during runtime (ibid.).

Elaboration of process models is carried out in plenary sessions, where all involved actors play through the model collaboratively, guided by the BPMS, and make changes to the process as appropriate. Changing the model of the process is not a trivial task for non-expert modelers in this phase, as a formal business process specification language is used here. The tool allows for extending process descriptions via dialogue forms and without directly manipulating the model. While this enables elaboration through virtual enactment, it does not provide sufficient support in terms of MSF4 and is currently being extended toward interactive prompting to elicit the missing model information during execution as proposed by Herrmann and Loser (2014). In the current prototypical implementation of the tool a human facilitator carries out prompting and model modifications. While this poses a limitation to the presented work, the overall methodology – being the core design artifact presented here – is not affected, as the facilitator does not intervene content-wise but only acts as an interface to the modeling environment.

The prompting interventions of the facilitator, however, need to be examined more closely in future research to enable an appropriate design of scaffolds (cf. MSF4).

3.4 Organizational alignment - a case study

The former section introduced a methodology to support the process of collaboratively articulating knowledge about work in organizations as a design artifact. The evaluation of this artifact with respect to requirements identified in Section 3.2 is described in this section. The aim of the research presented here is to contribute to articulating different views on a work process and facilitate the alignment of different views. This implies the existence of a shared work context in which different views in collaborative work can emerge. This shared work context, however, cannot be controlled or artificially created, as would be necessary for an experimental evaluation setup. Case study research (Yin 2009) thus remains as a suitable validation strategy. The *research questions* to be addressed here are twofold. Regarding articulation, evaluation needs to address how the identified ARs and MSFs are met by the methodology. Regarding the articulation results, evaluation needs to address whether the resulting models are syntactically valid and semantically sound. Underlying these research questions and concretizing them are the following two *propositions*: (1) The proposed methodology as a whole (i.e. comprising all its phases) enables domain experts without modeling experiences ("actors") to articulate and align their views on a collaborative work process and create a common artifact representing this aligned view. (2) This common artifact is a model of the work process as perceived by the actors, where the model is considered to be complete when all actors involved in the model creation process consider their views to be fully represented by the model. This model can be interpreted by and processed in an IS without further transformation.

3.4.1 Case study design

The *unit of analysis* for proposition 1 is a group of actors working together in the course of one modeling workshop. For proposition 2, the modeling result needs to be assessed. Consequently, the *data collection methodology* for proposition 1 needs to generate data about the acts of articulation and alignment happening during the application of the methodology, also capturing which behavior can be observed during the different methodological phases. *Data interpretation* needs to identify whether the phases meet their design criteria as described in Table 1. *Data collection* for proposition 2 needs to document those modeling results generated during the application of the methodology, which represent common artifacts which serve as the foundation for further processing: the model generated as an outcome of collaborative consolidation (acting as the baseline for elaboration), the result of the transformation process to an executable modeling language (as the first IT-interpretable model), and the model generated by elaboration through virtual enactment (as the final result). *Data interpretation* needs to assess the syntactic correctness of these models with respect to the use of modeling language and their usefulness for the indented articulation objective.

Following this research design, the case study has been designed to test the propositions. The AR and MSFs are the fundamental criteria for designing the methodology. Consequently, the properties of the methodology meeting these criteria should be observable in any of its applications. This objective justifies a revelatory single case design (Yin 2009), where a case needs to be selected in which the data collection requirements can be satisfied. In particular, this means that the outcome of the methodology needs to be applied in a practical work context (cf. data collection requirement for proposition 2: generate data on the usefulness for the intended articulation objective). Data to assess proposition 1 also can only be generated in-situ during a real-world application of the methodology. Data for the presented case thus were collected following a participant observation approach (Jorgensen 1989). In the following, the case setting is described after a summary of the observations is provided with respect to research questions 1 and 2. Section 3.4.3 discusses the findings in light of the research proposition formulated above.

3.4.2 Case description

The case is situated in the administration department of a university and addresses the procedures necessary to come to a funding decision for research materials or infrastructure. Research departments can apply to receive additional funding from the global university budget, if they are not able to cover the costs of materials or infrastructure for conducting their research.

The process of assessment and decision making for such applications historically was never formally established. This led to a lack of transparency in the decision process regarding both the decision criteria and the status of an application at a given point in time. In this case study, when a new CFO took office she set out to establish this process. The aim of this initiative was to make the progress and outcome of applications transparent to the applicants, and ultimately to have the whole process supported by the already existing workflow management system of the university. The methodology described above was used in a series of workshops to reach these aims.

Following the procedural model described in Section 3.3, the methodology initially was applied to reach common ground across all involved organizational entities of the not yet formally established process. The methodology was used to elaborate the model of the application process so that it provided a foundation for setting up process guidelines, forms, and workflow support. Four people from the university administration and one person representing the research departments were involved throughout the whole process. Modeling consisted of setting-the-stage, individual articulation, and collaborative consolidation in the initial workshop and elaboration by virtual enactment in a second workshop. A facilitator guided the whole process methodologically but did not intervene content-wise.

Representatives of the following organizational roles were involved throughout the whole articulation and elaboration process (names given in brackets are used as abbreviations when referring to them below). The list of activities refer to the anticipated tasks during the application process that led to the invitation of the respective person to participate in the workshops: *technician of a research department* (technician): filing application for funding, providing additional information as needed; *representative of university IT department* (IT dept.): providing domain expertise for decisions about IT-oriented applications; *CFO of university* (CFO): making final funding decisions, acting as the link to the executive board of the university for decisions on applications exceeding a given financial threshold; *head of controlling* (controller): preparing funding decisions for the CFO, assessing financial feasibility, communicating with the applicant; *head of financial administration* (head of finance): managing the ordering and inventory of material or infrastructure from approved applications.

Of these five actors, only the representative of the IT department had prior knowledge of business process modeling. The other actors only had operative experiences with the university workflow management system, without being explicitly confronted with the underlying process models. The group consisted of four female actors and one male actor aged between 32 and 45. The following section reports on the observations made during the implementation of the methodology.

3.4.3 Documentation of articulation process and outcomes

Setting the stage - The actors started with the “setting the stage” phase. The facilitator gave them the task to identify “everything that they considered relevant for the funding application process,” without imposing any further restrictions. The actors identified 14 concepts that were considered important in the context of the work process. After clustering these concepts, three main classes of concepts were identified. One cluster comprised the involved organizational roles, and the second cluster covered the relevant information and documents that were required. In the third cluster, the actors identified the major global steps that were necessary to complete the work process. As the actors were selected based on their anticipated involvement in the process, no major conflicting views were uncovered. Some wording issues were resolved, mainly between the members of the administrative departments and the technician, since different notions used by administrative staff to refer to information required during the application assessment were initially unclear to the technician. “Setting the stage” was also used to clarify the scope of the process. There were different viewpoints on whether the activities that happen in administration after a positive funding decision should still be included in the work process. As the technician and the representative of the IT department already identified potentially redundant activities happening in this later phase, the actors decided to include it in the articulation activities. The created model was filed electronically and printed for each actor in order to be used as a reference for consistent wording during individual articulation.

Individual articulation - The steps of the "articulation and alignment" phase were also performed using the card-based tool. In the initial step, all actors were asked to describe their activities within the process from their point of view following the approach described in Section 3.3.2. This phase required clarification on the meaning and use of EXCHANGE-elements for two actors. Referring back to the cluster including the relevant information items from the first modeling phase as an example for potential EXCHANGE-elements helped to resolve these issues. The step of "individual articulation" was completed in about 15 minutes without any further issues.

Collaborative consolidation - Collaborative model consolidation was performed using the cards created during individual articulation. The result of this part of the workshop is depicted in Figure 3.7, which shows the original model and a transcribed, anonymized version used for description here (coding scheme for numbers used in transcribed version: x denotes WHO-elements; x.y denotes WHAT-elements, where x is the responsible WHO-element; and x1-x2.z denotes EXCHANGE-elements, where x1 is the sending and x2 is the receiving WHO-element). Numbers in brackets refer to Figure 3.7 following the described coding-scheme.

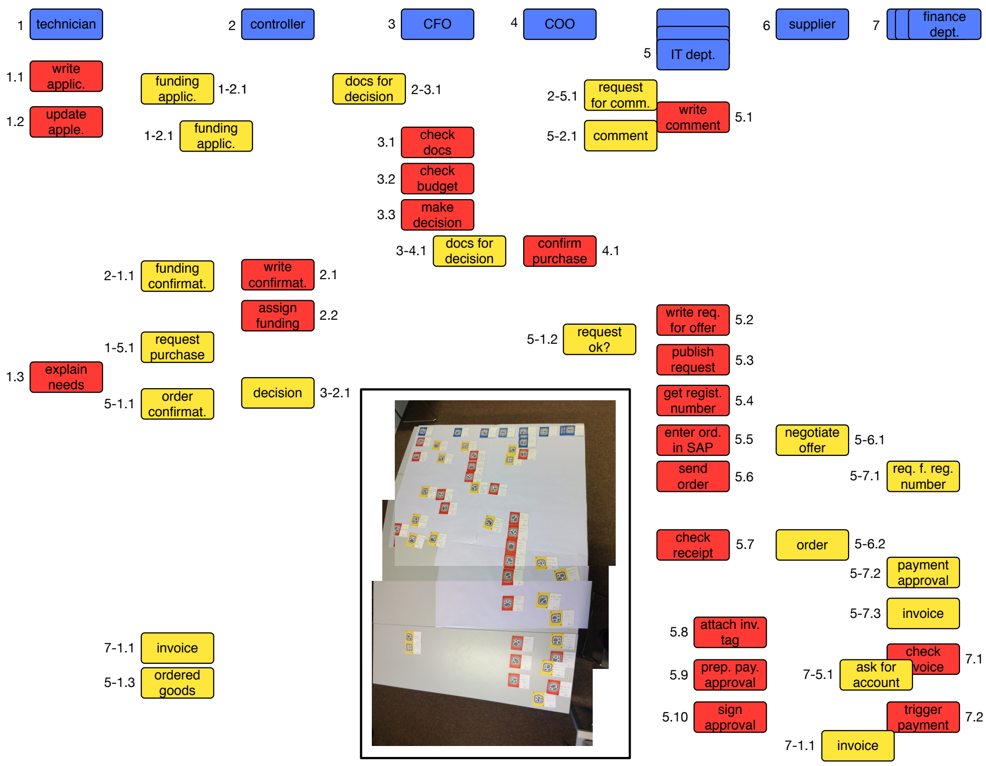

Figure 3.7: Card-based model resulting from collaborative consolidation

The technician (1) started with adding his elements, as he also triggered the process in reality by preparing the funding application at the research department (1.1). The controller (2) was involved as the second actor when the technician modeled the interaction of submitting the funding application form (1-2.1). The subsequent activities required further discussion, as the controller potentially needs to collect further information from the technician. This was not included in the latter's individually articulated model. After those issues were resolved, the CFO (3) became involved. When the controller passed on the prepared documents for the funding decision (2-3.1), the CFO immediately involved the IT department asking for a comment on the funding application. After receiving his answer, she would have been able to make a decision. At this point the first major change for the process was proposed. The controller recognized that she could request the IT department's comment in the preparation phase, making the actual decision process more efficient. All affected actors accepted this change, and the model was adapted accordingly (2-5.1 and 5-2.1).

From this point on, modeling continued without any major changes to the process as the actors originally envisioned it during individual articulation. One major change to the content of the application form was proposed when discussing the activities to be performed after a positive funding decision. As already anticipated during the setting the stage phase, the representative of the IT department (responsible for placing an order to external suppliers) and the technician (responsible for collecting initial quotes) discovered that both of them requested offers from potential suppliers. To avoid inefficiencies and double quotes, they agreed that the initial offers collected by the technician should be included with the application, so that this information could be passed on in the case of a positive funding decision. The controller, being responsible for handling those applications, agreed to this change on the condition that the processing of applications in the future was supported electronically. The representative of the IT department, responsible for the workflow management system, agreed to implement this functionality in the operative system. This change did not immediately affect the process model, as the steps remained unchanged. Still, the information to change both the content and the representation of the application form was documented as an annotation to the respective EXCHANGE-element. The first workshop ended with an initial version of the work process to which all participants could agree.

Model transformation - For the second workshop, the model was transformed to a S-BPM process model (cf. Figure 3.8) using the transformation tool as described in Section 3.3.4.1. Missing information and ambiguities (e.g., EXCHANGE-items 7-1.1 and 5-1.2 lack a target WHAT-item in the lane of WHO-item 1) were identified and resolved during transformation. The facilitator guided this step, as interactive guidance technically was in an embryonic stage and thus could not be operatively deployed. The result was deployed to the BPMS used for the "elaboration through virtual enactment" phase. The same actors as in the first workshop gathered in a co-located setting with the facilitator and an additional modeler responsible for making changes to the model as required during enactment. The latter was necessary due to the limitations of the current tool prototype used for virtual enactment (cf. Section 3.3.6) and consequently was instructed not to intervene regarding the content.

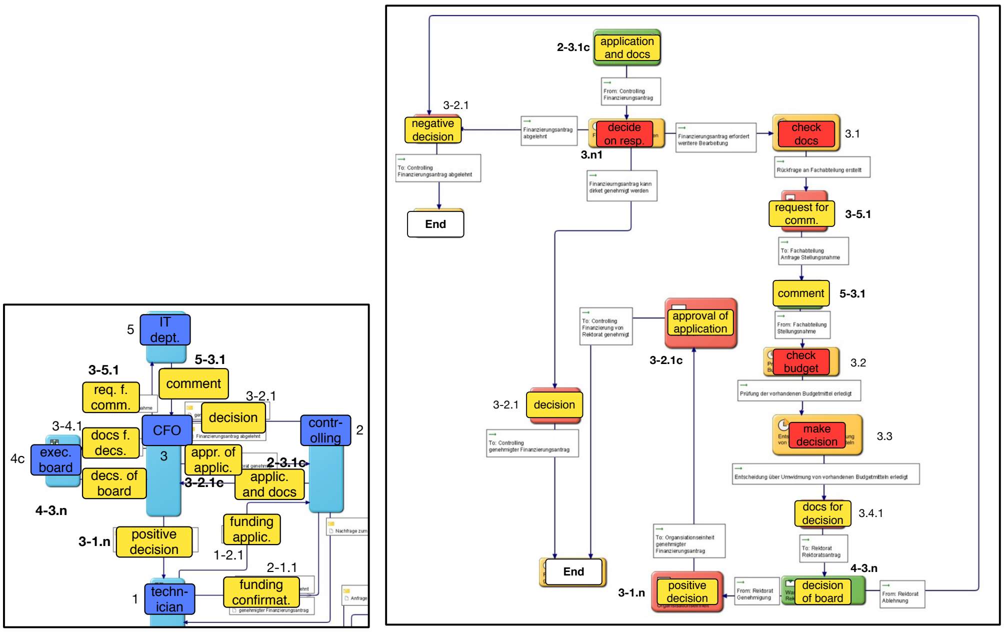

Figure 3.8: Excerpt of S-BPM model representation (already elaborated) – left: part of subject interaction diagram showing CFO's (3) modified interaction (changes printed in bold); right: extended behavior diagram of CFO (changes printed in bold)

Elaboration through virtual enactment - Playing through the process contributions of the technician and the controller did not reveal any need for changes or extensions. Major changes to the process, however, were required for the CFO's part, reflected in Figure 3.8 and described in the following (numbers in brackets refer to elements shown in Figure 3.8). The CFO wanted to reflect the criteria for funding decisions in the process model, and she consequently extended the model with a decision element (3.n1) that reflected the different options of coming to a decision for a funding application. These changes to the process model were included immediately during execution and were validated in the same step by executing them iteratively. These changes to the behavior of the CFO triggered cascaded changes as described in Section 3.3.4.2. An example of such cascaded changes is the addition of the executive board of the university as an additional instance for decision making if the funding application exceeds a certain amount of money (cf. case 5 in Section 3.3.4.2). In the subject interaction diagram, the existing subject 4 in Phase 2 originally referred to the university chief operations officer (COO), who had to be informed in certain cases. However, this was changed to represent the executive board (4c); The behavior of the CFO affects communication with the executive board (cf. case 4 in Section 3.3.4.2, reflected in 3-4.1 and 4-3.n in Figure 3.8). In addition, the behavior of the controller requires changes, as decisions need to be prepared differently in such cases (cf. case 3 in Section 3.3.4.2, reflected by the altered incoming communication 2-3.1c in Figure 3.8). Additionally, the communication with the IT dept. (5) was changed back to be carried out by the CFO (3), as the latter argued that making informed decisions was easier for her if she could interact with the domain experts directly (reflected in 3-5.1 and 3-5.2, which substitute 2-5.1 and 2-5.2 from the result of Phase 2). In addition, the CFO insisted that she should be the one to inform the technician (1) about decisions made by the executive board (reflected in 3-1.n in Figure 3.8). The remaining process was again enacted without any major changes and is not described here in more detail.

After "elaboration through virtual enactment" was completed, the process was transferred to an operative instance of the BPMS. The participants were granted access to this platform to experimentally implement the new process in real-world cases. After a testing phase of three months, a brief reflection meeting was held to allow for mutual feedback and to collect ideas for further improvements to the process. In this step only minor modifications to the sequences of activities of the controller were made, and thus the remainder of the process was not altered. The process was then exported in its final version and provided to the IT department for implementation in the university's global workflow management system.

3.4.4 Discussion

The case study described in the last section has made visible different aspects of the proposed methodology and tools that are discussed here with respect to the original aim of this work.

The primary goal of this work is to facilitate the development of common ground on a work process across all involved actors. This aim is supported by fulfilling the ARs and MSFs described in Section 3.2.1 (cf. proposition 1 as described in the introduction to Section 3.4).

ARs 1 and 2 (individual articulation, collaborative consolidation, clarification on scope and setup of work environment) are implemented via the design of the methodology and are reflected in Phases 2 and 3 of the procedural model ("articulation and alignment" and "elaboration through virtual enactment") by different methodological approaches. In Phase 2, alignment was provoked by explicitly articulating individual models in a first step and consolidating them in a second step. The layout guidelines for model consolidation were successfully deployed as a structural scaffold in this case (cf. *MSF 4*). In Phase 3, individual articulation was facilitated by virtual enactment of the activities of each involved actor. The communication-centric modeling approach used in this phase also triggered collaborative alignment, where necessary. Virtual enactment here acted as a procedural scaffold guiding the elaboration process (cf. *MFS 4*).

AR 3 (convergence of the understanding of a scope of work) was appropriately supported by the concept map-based collaborative modeling approach used in Phase 1 ("setting the stage"). The incremental rise in modeling language complexity throughout the phases in particular helped the inexperienced modelers become familiar with reading and understanding models, and using them as a form of expression for their own viewpoint. Progressing from semantically open concept mapping in setting-the-stage over single-perspective flow-oriented modeling in individual articulation to multi-perspective communication-oriented modeling during collaborative consolidation thus appropriately implemented *MSF 2* while still maintaining the goal of creating a model representation that adheres to a formal syntax, allowing for further processing in an IS. This goal is also supported by the implementation of *MSF 4* via the enactment component that enables selective generalization to case-independent models until a common model of the full work process is created (*MSF 1*).

A drawback of the reduced set of modeling elements became apparent during collaborative consolidation. The lack of a structured approach to specify the content of EXCHANGE elements seems to lead to "vague" definitions (Herrmann et al. 2002) that neither reflect nor facilitate reaching common ground on the transferred information or artifacts. The opportunity to annotate informally information about these aspects (cf. *MSF 3*) was hardly used in the case study and does not seem to replace appropriately a structured modeling approach in terms of articulation and alignment support.

AR 4 (identifying and keeping track of conflicting issues) was implemented in the case study by using the card-based tool for collaborative consolidation. The representation of conflicting issues is imminent to the modeling approach, as it requires matching associated or equivalent cards. Conflicts are made explicit whenever this matching fails. This approach has worked well in the present case study, with respect to both process support and results. The lack of matching cards was hardly ever accepted without further discussion, thus avoiding the undesirable quick consensus building approach mentioned in Section 3.3.3. Identified issues, however, rarely led to extensive discussions but were resolved rather quickly. In the feedback session, participants attributed this to the fact that they did not have conflicting viewpoints but rather suffered from a lack of transparency. Still, according to immediate feedback after the workshop, uncovering different perceptions and resolving them worked well, and everybody was satisfied with the resulting model. This is backed by the observation that no changes to the operative instance of the work process were requested during the pilot phase.

While resolution of conflicting issues was facilitated well in Phase 2, observations were different in Phase 3. The switch between different model visualizations from card-based consolidation to computer-based elaboration initially made it hard for participants to recognize the semantic equivalence of both models. This issue was resolved, when virtual enactment was started and tracked simultaneously in both model versions. The setting in which the elaboration workshop was held, however, reduced the involvement of the actors in modeling. They took no active role in modeling anymore, and left finding appropriate model representations to the expert-modeler, who was perceived to be responsible for making the model elaborations, although his passive role was clearly articulated. Although none of the actors has claimed this to have a negative impact on the modeling outcome, the validity of their perception is questionable. Observations have shown at least two cases where the actors accepted content-wise changes proposed by only one actor and made by the expert-modeler without questioning them. First, experiments with enabling model elaborations done by the actors themselves during virtual enactment using an interactive elaboration component based on prompting embedded in the enactment environment were made since then. Initial results with this setup were promising but require further evaluation before they can be used in real-world settings.

The aim of generating a model that is a syntactically valid and semantically sound (cf. proposition 2) was reached. Analyzing the process of model creation, however, reveals some limitations of the current tool support, which were resolved in the case study by interventions of the facilitator. Future work will have to address these limitations and extend tool support towards providing better procedural scaffolds for model transformation and elaboration.

3.5 Conclusions

This chapter has proposed a methodology that enables people, who are not expert modelers, to articulate and negotiate their use of work processes in the form of collaboratively created conceptual models. The design of the methodology prioritizes ease of use and understandability over semantic completeness during articulation. Elaborating these models towards a representation of the process in all its variations is done in a separate phase. The methodology builds upon two compatible modeling languages, of which the first supports case-based articulation and alignment of collaborative work models, and the second is executable in IT systems, representing work processes in all their variants. Using different forms of representations is necessary, as different requirements must be met for human actor interpretation and technical actor interpretation (Zarwin et al. 2014; Krogstie et al. 2006).

The methodology is backed by a set of tools that provide scaffolds for the methodological steps. Most prominently, a non-technology-enhanced, card-based tool for performing individual articulation and collaborative consolidation is presented. The result of articulation and consolidation is processed in a transformation step, in which a tool generates an executable version of the articulated model. The virtual enactment BPMS processes this model and allows to generate a description of the work process in all its variants.

Contributions - The proposed methodology, backed with the current tool prototypes, has been validated by the case study described in Section 3.4, which confirmed that the methodology meets the requirements set up in Section 3.2.1. The major contributions of the present work consequently are, firstly, the integrated chain of modeling steps, which is a novel way of guiding actors with no prior modeling experiences through articulating, aligning, and refining their views on collaborative work processes, and results in syntactically valid and semantically correct business process models. The second is the card-based modeling language designed for collaborative articulation and alignment of work process knowledge while maintaining syntactic and semantic compatibility to formal, executable process modeling languages such as S-BPM, together with the toolset that allows for transforming and elaborating these models interactively. This is novel, as it meets the requirement of modeling objectives pursued in both natural modeling and formal modeling (Zarwin et al. 2014). From a practical perspective, the results of the case study show that organizations can expect the identification of inefficiencies that arise from the division of labor in collaborative work (such as the duplication of requesting offers from potential suppliers) and the development of process models that better reflect the requirements of the operative staff (such as the request of the CFO to consult with domain experts herself).

Limitations - The present work has some limitations. In terms of research design, its empirical validation is rather limited, as the present chapter only reports on a single case study. However, it still shows that the design objectives of the methodology have been reached and gives valuable first insights for potential areas of improvement. Following a design science approach, this provides the foundation for the next iteration of the designed artifacts. Technically, the implementation of the interfaces between the used tools was not sufficiently stable for unattended actor-driven operation. Several manual interventions in the transformation process between the card-based model and the S-BPM model have been necessary due to limitations of the interactive model transformation algorithms. This, however, has not affected the application of the methodology and thus has no impact on the outcome of the case study. Methodologically, the resolution of conflicting viewpoints during collaborative consolidation has not yet been sufficiently researched. While the descriptive analysis of the identifiable behavior during consolidation provides a starting point for choosing appropriate interventions, further research in this area should lead to improvement of the methodology. In general, the focus of research has been put on single work processes. Dependencies between different work processes, which are common from an organizational perspective, are not explicitly addressed methodologically, but are only considered indirectly via the involved actors, if they chose to justify their arguments during consolidations based on such dependencies. Whether and how a more comprehensive perspective considering collections of interdependent process can be considered in the methodology remains an open issue to be addressed in future research. Validation by or involvement of stakeholders, who are not operatively participating in the work process but are responsible for or affected by them, could be a potential approach to address this issue.

Future Work - In future work, further experimental and practical evaluation of the methodology is planned. This includes deploying it in more diverse organizational settings and evaluating the effects of its components in more detail. This will require evaluation setups that go beyond participatory observation and enable a structured review of the collaborative articulation and alignment processes of the actors in the different phases and how they interact with the designed artifacts. Approaches for an empirical evaluation of the addressed phenomena can be found in the field of collaborative modeling support. Rittgen (2007) provides insight in how to evaluate the collaborative modeling part of the methodology based on the semiotic qualities observable during modeling. Claes et al. (2013) focus on analyzing the process of process modeling and anchor their metrics on dynamic aspects observable during model creation. Hoppenbrouwers & Rouwette (2012) use the concept of "focused conceptualizations" to separate the collaborative model building process along its different conversational topics and analyze them regarding different aspects of modeling (e.g. required input, desired outcome, participants, guidance measures, type of abstraction activity, etc.). Ssebuggwawo et al. (2013) propose a framework for selecting and combining evaluation methods to address different aspects of collaborative modeling processes. Instantiating this framework would allow to comprehensively describe the effects caused by the phases of the proposed methodology. The findings from these evaluations will further refine both the methodology and the toolset. Future iterations of the design will focus on improving technical support for elaboration through virtual enactment (e.g., providing interactive scaffolds for potential modifications of the model) and for the model transformation process (e.g., interactively merging several case-based models to provide a more comprehensive foundation for elaboration through virtual enactment). Finally, the work presented here will be embedded in an IS, supporting organizational learning processes as a frontend for articulation, reflection, and distribution of knowledge about organizational work.

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4 Linking natural modeling to techno-centric modeling for the active involvement of process participants in business process design[1]

4.1 Introduction

During the last decades, there is a rapidly growing interest on Business Process Management (BPM), revealed by the plethora of relative emerging technologies. Such technologies include business process modeling languages offering the means to design technically interpretable business process models like BPMN (OMG 2006), EPCs (Mendling 2008) and S-BPM (Fleischmann & Stary 2012), tools for business process analysis like Signavio (www.signavio.com), business process management systems (BPMSs) providing the required infrastructure for business process modeling, analysis and enactment like Bonita BPM (www.bonitasoft.com) and AristaFlow (www.aristaflow.com), and sophisticated BAM (Business Activity Monitoring) suites enabling performance tracking of business processes like Oracle BAM (www.oracle.com/technetwork/middleware/bam/overview/index.html).

The central concept behind all these technologies is the business process model, which is designed, analyzed, implemented, enacted, monitored and evaluated continuously in the course of the business process management lifecycle (Weske 2010). However, in contrast to the wide variety and rapid evolution of such technologies that support the management of a business process model throughout its lifecycle, less progress has been made on how to design a business process model in terms of a well-defined methodology (Nurcan & Schmidt 2015) and even less on how to elicit the model from the real world cases (Mauser et al. 2009).

[1] This chapter is identical in terms of content to the accepted final version of the article „Oppl, S., & Alexopoulou, N. (2016). Linking natural modeling to techno-centric modeling for the active involvement of process participants in business process design. International Journal of Information System Modeling and Design, 7(2)“. It has been modified to provide consecutive numbering of sections and figures throughout this thesis.

According to Weske (2010), elicitation and modeling together correspond to the design stage of the BPM lifecycle. The reason they are not depicted as separate phases is that they are not conducted in a sequential manner. Rather, they are performed interchangeably until a process model is reached that sufficiently reflects the real-world process. Typically, a process analyst, i.e., a person qualified to drive the design and analysis procedures, with competence on one or more process modeling languages, interviews a representative group of workers, in order to extract information on how the work is done for a specific business process. Subsequently, the process analyst uses this information to build an initial process model. Afterwards, the analyst proceeds with its calibration, which involves iterations of comparisons between the model and the actual process through further interviews with the involved participants, and exploitation of the discrepancies between the two, to improve the model. This procedure is repeated until model accuracy is judged to be acceptable. The construction of the model is typically based on hierarchical top-down modeling like the approach presented by Silver (2009). This approach starts with an abstract model following the strategies and policies set by top management. The abstract model is gradually refined into a more fine-grained representation of work based again on information acquired from managers. However, during the decomposition procedure, process participants may also come into play.

Generally, in the above mentioned approach, process analyst acts as an intermediate between the workers and the model created. Although process analysts specialize in process design, mediation per se may create delays in the process modeling procedure and mismatches between the model and the real world case, as in such an approach elicitation and modeling are tackled as two discrete steps. A possible way to avoid such kind of problems would be to actively involve process participants in process modeling (Front et al. 2015) and enable them to express themselves directly on the model, tightly interweaving in this manner modeling with elicitation. Modeling that is driven from process participants yields a bottom-up approach that creates models depicting how work is actually done. Moreover, through such an approach the tacit knowledge of workers on how to operate the real organization can be exploited (Dix & Gongora 2011). For tacit knowledge to be even better exploited, collaboration among workers during elicitation should be also promoted (Rolland et al. 1998; Forster et al. 2013). This is in contrast to the classical approach, where each worker is usually interviewed individually.

However, actively involving process participants in process modeling creates a challenge. Process participants are not expected to have modeling skills and usually, as also stated by Prilla & Nolte (2012), they are not willing to learn a modeling language with a strict syntax and semantics and many different symbols. What they would prefer would be to externalize their knowledge through diagrams that are as simple as possible in terms of both syntax and semantics. Zarwin et al. (2014) stress the importance of *natural modeling*, as they call it. With the term natural modeling, the authors aim at shifting the focus of attention from the technical and formal aspects of modeling to human aspects, since modeling has always been a human-intense activity. For modeling to be widely accepted, Zarwin et al., claim that it should be as natural as possible. To this end, they specified three principles: 1) modeling should be based on intuitive symbols and constructs, 2) modeling should be collaborative, so that models can serve as vehicles of communication facilitating knowledge sharing and promoting negotiation and commonly agreed-upon decisions, and 3) modeling should be flexible in a sense that the symbols do not have a predefined meaning but rather the language used should emerge dynamically based on the situation at hand. They, however, also claim, that – if the ultimate goal of the models produced is their technical processing – modeling support needs enable modelers to work in a continuum between "natural and formal modelling", which "should be fundamentally understood as the two polarities" (Zarwin et al. 2014) (p. 29).

The purpose of this chapter is to present a business process design approach, which explicitly addresses this gap by enabling natural modeling practices while at the same time maintaining a well-defined bridge towards techno-centric (formal) modeling. Through the adoption of natural modelling principles, the proposed approach, which is called CoMPArE/WP (Collaborative Model Articulation and Elicitation of Work Processes), achieves effective involvement of process participants. Effectiveness in this context refers to the extent the participants are facilitated in externalizing their tacit knowledge and reflecting it on the business process model as well as to the acceptance of the approach by the participants. Being a business process design approach aiming at supporting the whole BPM lifecycle, CoMPArE/WP deals also with the transition of the model developed by process participants to a techno-centric process model, meaning that it can be processed and enacted using a BPMS.

In specific, this chapter is structured as follows: First, background information is provided regarding the existing elicitation techniques and it is explained which of them have influenced the proposed approach. Subsequently, the discrete components of the CoMPArE/WP approach are analytically described and then an illustrative case is presented as a proof of concept. Next the related work is discussed and finally our conclusions and future work are presented in the last section.

4.2 Background

BPM is regarded to be intimately related to system engineering and thereby the mental approach is the same (Bhaskar et al. 1994). In system engineering which has been an active field for more than 20 years, a large number of elicitation techniques have been developed, targeting the identification of system requirements. This might be another reason for the fact that, in BPM, process elicitation has not been adequately emphasized. There is indeed a fairly large bibliography on elicitation techniques regarding either requirements in system engineering or knowledge in knowledge engineering, which is also a rather old discipline, dating back to the decade of 80's. In the following, the most common techniques are briefly reviewed.

Interview-based techniques are among the most well-known methods for eliciting knowledge (Mohammad & Saiyd 2010; Sagheb-Tehrani 2009). Interviews may be well structured, comprising a very specific sequence of questions that the interviewee is asked to answer. As such, there is an organized form of communication between the interviewer and the interviewee. In contrast, unstructured interviews allow questions based on the interviewee's responses and constitute a looser form of discussion.

Focus groups (Massey & Wallace 1991) involve extracting information from the discussion among a group of stakeholders about some topic of interest to the researcher, exploiting thus the collective knowledge of the group. For this technique to be successful, it is important to ensure a group composed of well-chosen participants in terms of their relation to the corresponding enquiry, and additional parameters such as their knowledge and expertise and their organizational position.

Another technique for knowledge elicitation is protocol analysis (Goguen & Linde 1993). In protocol analysis, domain experts report on the process they follow in performing a task or solving a problem. The domain experts can keep notes or think aloud in parallel to their actual work.

Scenario-based elicitation techniques (Carroll 2000; Go et al. 2004) extract knowledge from domain experts by engaging them in specific cases of how to use the system under development or in concrete manifestations of the problem under consideration. Scenarios, which have been extensively employed in software engineering (Weidenhaupt et al. 1998; Holbrook 1990; Kavakli et al. 1996), can be used in combination with prototyping. Prototyping (Beaudouin-Lafon & Mackay 2003) may be an interactive screen (normally consisting of hypertext with no real data behind it), a mock-up (such as a PowerPoint), a navigation flow (such as a Visio diagram), or a storyboard. A technique that can be adopted in conjunction with prototyping is the participatory design (Kensing & Blomberg 1998; Muller et al. 1993). Participatory design actively involves users in all phases of the design process. Users are not simply consulted at the beginning and asked to evaluate the system at the end or in specific milestones but they are treated as partners throughout.

An alternative category of knowledge elicitation is based on *observation* (Mohammad & Saiyd 2010; Sagheb-Tehrani 2009). Observation is considered a technique eligible for acquiring tacit knowledge. In this technique, experts are visited on site and monitored during their work. Observation is also called contextual inquiry and can be passive, where the analyst merely watches someone working but does not interrupt or engage the worker in any way, or active, where the analyst asks questions throughout the process to be sure he/she understands and even attempts portions of the work.

Introspective techniques complement the body of elicitation methods described above. Acquisition of tacit knowledge is the objective of the repertory grid analysis (Hudlicka 1996). This is a technique borrowed from experimental psychology, designed to access internal mental structures. It is used to indirectly determine the individual's view of the world, for example by asking simple questions about similarities and differences between domain entities or attributes, or by asking the individuals to rate the similarities of two entities on some numerical scale. Repertory grid analysis may be used in combination with laddering (Corbridge et al. 1994). Laddering is a technique for clarifying the relations between the constructs which have been extracted by the repertory grid analysis enabling a hierarchy of concepts to be established. Card sorting (M. Wang & H. Wang 2006; J. R. Wood & L. E. Wood 2008) is another technique developed by psychologists used also for constructing structuralized piles of concepts. The concepts are first identified and written onto simple index cards or post-it notes. The users then arrange these to represent the groups or structures they are familiar with.

All the above techniques have both pros and cons and each of them is applicable for a specific problem category. Therefore, a combination of them might prove more effective for extracting the desired knowledge from domain experts (Hickey & A. M. Davis 2003). For comparisons regarding these techniques, the reader is referred to (A. M. Davis et al. 2006; Sagheb-Tehrani 2009; Goguen & Linde 1993).

Despite the availability of elicitation techniques from the field of systems and requirements engineering described above, in traditional BPM approaches elicitation still is often conducted by a process analyst with workers taking the role of information providers, rather than being actively involved in model creation and alignment of different viewpoints that need to be integrated (Hjalmarsson et al. 2015). In recent years, research in this field has picked up the idea of the active involvement of process participants in modeling and has led to approaches that combine characteristics of some of the aforementioned techniques to promote their collaboration during process design (e.g. (Rittgen 2009b; Front et al. 2015; Türetken & Demirörs 2011) – cf. Section 4.5 on related work below). The approach proposed in the present chapter also follows this path and adopts ideas from participatory design, card sorting and scenario-based elicitation. In the following, we introduce our method, show its feasibility in a case study and finally reflect its design against those approaches from related work that pursue similar objectives.

4.3 The CoMPArE/WP Approach

CoMPArE/WP is a method based on natural modeling practices which at the same time maintains a well-defined bridge towards techno-centric (formal) modeling. In the following, we use the method notion introduced by Goldkuhl et al. (1998) to describe about the method and its implementation in detail and show how it can be used for business process design. Goldkuhl et al. (1998) suggest to consider the following aspects when providing a structured description of a method following a question-oriented paradigm: A method builds upon a *perspective* it adopts to determine on what it wants to achieve ("What is important?"). It consists of different *method components*, which are characterized by three closely linked aspects: *procedure* ("What questions to ask?"), *concepts* ("What to talk about?"), and *notation* ("How to express answers?"). The method components together form a methodological structure that is referred to as *framework* ("How are the questions related?"), which describes how those aspects are interrelated and also determines how the method components are linked with each other. A method is implemented by *co-operation forms* (Who asks? Who answers?). In the following, the description of CoMPArE/WP is structured along these aspects. We start with an overview of the whole method, and subsequently detail on each component.

Perspective

CoMPArE/WP adopts the perspective on modeling support argued for by Zarwin et al. (2014) and consequently aims at closing the gap between anthropo-centric (natural) modeling and techno-centric (formal) modeling. To achieve that, it adopts the principles of natural modeling but at the same time it supports in a well-defined way the derivation of executable models. The leading question to be answered by the participants implementing the method is: "How is a business process to achieve a given organizational goal (to be) implemented?"

Framework

The methodology design is informed by a multi-component framework that enables process participants to gradually develop a comprehensive model of their business process in a cooperative way without requiring them to be familiar with techno-centric modeling languages.

The methodology of CoMPArE/WP comprises three related method components as depicted in Figure 4.1.

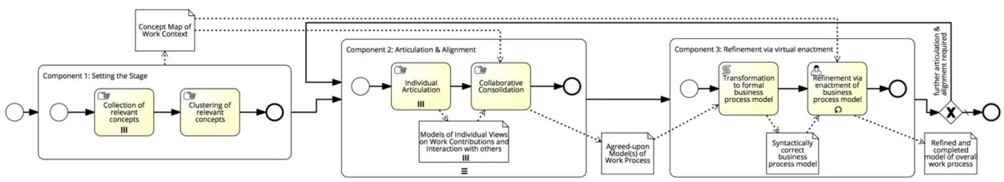

Figure 4.1: The CoMPArE/WP approach represented as a BPMN process

These components aim at enabling modeling practices adhering to the principles of natural modeling in the initial phases of business process elicitation and then gradually developing more sophisticated techno-centric models without confronting users with their complexity. An overview of these components is provided in the following. More detailed descriptions of the component are provided in the following subsections, describing them to the level of actual implementation.

- *Component 1*: Setting the Stage
  - *Procedure*: What is important in the context of the business process?
    - *Concept*: When implementing this component, modeling participants try to find a common understanding about the scope of the business process and the notions to use to refer to the relevant concepts. Scope herein refers to where the business process starts, where it ends, and which aspects are to be addressed when implementing it. Groups of modeling participants with heterogeneous backgrounds in particular might have an issue with wording when aligning their different views. The notions used to refer to different aspects of the business process are thus explicitly captured.
    - *Notation*: A semantically unconstrained notation similar to concept mapping is used in this component to allow modeling participants to express their concepts without requiring them to initially adapt to a given modeling language. This addresses the first requirement of natural modeling.
- *Component 2*: Articulation and Alignment
  - *Procedure*: How do we / should we (the modeling participants) collaborate to implement the business process in our organization?
    - *Concept*: Natural modeling requirements 2 and 3 are addressed in the second component, where modeling participants are required to collaboratively agree upon who should be involved in implementing the business process, what contributions the participants are expected to make in the course of the business process, and how they will interact to achieve their goals. Participants are flexible and how they semantically address those three categories but ultimately need to agree upon a common set construct semantics. The description of the results is restricted to a single case of implementing the business process, thus reducing complexity of its representation in this component.
    - *Notation*: Due to the simplified semantic requirements, component 2 makes use of a simplified, generic notation for describing collaborative business processes, which will be further elucidated in the following paragraphs. This generic notation enables semantic adaptation to the requirements of the modeling participants and therefore meets the first requirement of natural modeling (i.e. "intuitive constructs").
- *Component 3*: Refinement via Virtual Enactment
  - *Procedure*: How should the business process be implemented to appropriately address the potentially different contexts it is executed in?
    - *Concept*: Modeling in component 2 focuses on a single case of the business process to reduce complexity of the modeling and alignment procedure. Component 3 conceptually addresses this shortcoming by elaborating the model in an interactive way towards a comprehensive representation of the business process. This is achieved through refinement during virtual enactment, i.e.

engaging modeling participants in identifying problems and gaps of their initially agreed upon model by playing through it and elaborating it concurrently.

- *Notation*: In component 3, no graphical notation for supporting modeling is used at all for the participants. They use web-based dialogue forms to describe deviations from the business process developed in component 2. Technically, these deviations are incorporated in a BPMN model of the process, which is maintained in the background.

The whole modeling framework is iterative, enabling the flexible combination of design components as the shared understanding about the business process evolves over time and potentially uncovers additional aspects to be addressed. Flexibly combining the three components enables the adaptation of the design procedure to the business process at hand (higher complexity requires more overall iterations), to the amount of divergent views that is present in the group of modeling participants (more divergence requires more iterations of component 2) and to their skills in abstraction and modeling (higher skills enable more complex changes to be made during virtual enactment). Selecting the appropriate steps in an ongoing design process is the task of a modeling facilitator. The selection is made based on the observed situation in the group of the modeling participants and the desired outcome in terms of elaborateness of the resulting model.

Co-operation Form

All components are carried out in a workshop setting, where the modeling participants work on creating a shared artifact. However, component 2 comprises an initial step of individual activity without any interaction to capture the different participants' views on the business process, before collaboratively consolidating those views to an agreed upon model.

The methodology enables process participants to gradually develop a comprehensive model of their business process in a cooperative way without requiring them to be familiar with techno-centric modeling languages. As in the participatory design (Kensing & Blomberg 1998), in CoMPArE/WP process participants are actively involved in process design. They articulate their individual views on a work process to eventually co-operatively develop an agreed-upon business process model. Modeling practices used in this methodology, are not performed sitting in front of a PC screen, using some kind of software for process modeling. Instead, participants use cards with different colors which are assigned specific semantics during the modeling procedure. Like in card sorting (J. R. Wood & L. E. Wood 2008), participants create conceptual structures using the cards. Employing tangible means to conduct process modeling has already been proposed in the literature (Luebbe & Weske 2011; Oppl & Stary 2014). Using tangible means like cards instead of sophisticated software allows also technologically illiterate workers or, in general, workers that do not feel comfortable with technology to take part in modeling and overall makes modeling more enjoyable and appealing to modeling participants.

In the following, we further detail the description of those components in separate sections by using again the structure of *perspective, framework* and *co-operation form. Perspective* elaborates on the conceptual foundations for each component. *Framework* describes internal structure of a component, including *sub-components*, the addressed *procedures* for each (sub-)component, their respective *concepts* and the *notation* elements used for representing them, and puts them into mutual context. *Co-operation form* describes the actual implementation of each component in a CoMPArE/WP workshop.

4.3.1 Component 1 - Setting the Stage

Process participants do not necessarily share a common understanding of the organizational setting of the business process and which concepts to use for describing it Sarini & Simone (2002). Component 1 aims at "setting the stage" to enable co-operatively creating a business process model in the later components. It establishes a common understanding of the scope of the business process and of the concepts used for referring to its relevant aspects.

Perspective

Component 1 is based upon research on collaborative concept mapping as a means to create common ground (van Boxtel et al. 2002; Gao et al. 2007). Concept mapping is a method for externalizing and reflecting knowledge about real world phenomena (van Boxtel et al. 2002), such as business processes, without semantically constraining the participants to use certain language constructs when expressing their concepts. The question guiding concept mapping component 1 is: “What is important in the context of the business process?”. This focusses participants on the subject of discourse, while deliberately leaving open, which aspects actually are relevant as well as which constructs are used to describe them.

Semantically open modeling has been shown to be an appropriate approach to address this issue (Faily et al. 2012; Engelmann & Hesse 2010; Trochim et al. 1994).

Framework

Component 1 consists of two sub-components that support modeling participants in finding a common understanding about the scope of the business process and the notions to use to refer to the relevant concepts. Sub-component 1 is concerned with the collection of relevant concepts, whereas sob-component 2 aims at consolidation and clustering of the concepts collected in the former step:

- *Component 1.1*: Collection of relevant concepts
  - *Procedure 1.1.1*: What are the important elements in the context of the business process?

   - *Concept*: Modeling participants individually, without interaction with each other, collect all elements they consider important or relevant in the context of the business process. Collection deliberately and explicitly is not constrained to any particular types of elements.
   - *Notation*: Each element is noted on a white card. Participants are asked to sort their cards in a stack, starting with the most important one.
- *Component 1.2*: Clustering of relevant concepts
  - *Procedure 1.2.1*: How are the collected elements related to each other?
    - *Concept*: Modeling participants determine clusters of elements that are related with each other according to some criteria. The criteria for clustering are determined by the modeling participants themselves collaboratively.
    - *Notation*: The white cards bearing the named elements are placed on a shared modeling surface. Clusters of elements are represented by spatially arranging the corresponding white cards in a way the participants perceive to appropriately represent the cluster.
  - *Procedure 1.2.2*: Are there elements using the same notion for different concepts or vice versa?
    - *Concept*: Modeling participants might use different notions to refer to the same concept and vice versa during the trial collection of relevant elements. Different notions for referring to the same concept are identified during collaborative clustering and the ambiguity has to be explicitly captured. The same is true for different concepts referred to with the same notion by different participants.
    - *Notation*: Cards, which have been identified to represent the same concept but bear different notions, are stacked, the topmost card bearing the notion the participants agree to use further during the workshop. Cards bearing the same notion but referring to different concepts are placed separately on the modeling surface and are further elaborated with additional textual modifiers, which clarify their different meanings.

Co-operation form

The modeling participants perform the following steps as a group to co-operatively build a concept map:

- They individually collect a set of elements (depicted on white cards) they consider relevant in the context of the business process under design. The types of the elements remain unconstrained. All modeling participants assign names to each of their elements individually.
- Each modeling participant presents each of his/her elements separately, one after the other. The element is added to a shared modeling surface accessible to all actors. The other modeling participants are asked to check, if they have also created an element representing the same real-world concept (independently whether they used the same name or not) and resolve such issues according to the described methodology.

  - Participants group together elements that are of the same type (e.g., persons, tools, documents, ...), making the first step towards conceptual abstraction. Initial clustering and association specification can be performed while adding concepts in step 2. A final round of collaborative clustering and association specification after all elements have been added completes the stetting-the-stage design step.

4.3.2 Component 2 - Articulation and Alignment

Component 2 contains two sub-components, namely "Individual Articulation" and "Collaborative Consolidation", which together lead towards semantically more constrained models eligible for business process representation. During this components, the participants use results of component 1 as a reference and implement a multi-perspective articulation approach to process modeling (Mullery 1979). This separation of individual articulation and collaborative consolidation facilitates knowledge sharing and promotes negotiation and commonly agreed-upon decisions. The consolidation process leads to the documentation of a shared understanding about the business process, in accordance with the second principle of natural modeling.

Perspective

Existing research (Santoro et al. 2010; Fahland & Weidlich 2010; Kabicher & Rinderle-Ma 2011; Lai et al. 2014) suggests that starting modeling based upon a concrete work case makes it easier for process participants to develop an understanding of the concepts necessary to describe a business process in an abstract conceptual model. The leading question for this component is: "How do we / should we (the modeling participants) collaborate to implement the business process in our organization?"

Framework

Component 2 requires modeling participants to collaboratively agree upon who should be involved in implementing the business process, what contributions the participants are expected to make in the course of the business process, and how they will interact to achieve their goals. This component conceptually again is split in two sub-components, where the first one focusses on procedures concerning individual contributions to the business process, and the second one aims at consolidating these contributions to an overall model:

- *Component 2.1*: Individual Articulation: The following questions are not necessarily to be answered in the given sequence but should all be represented in the final modeling result. The whole component is carried out individually, without interaction with other modeling participants.
  - *Procedure 2.1.1*: What is my role in the business process
    - *Concept*: Modeling participants name their own role in the business process

  - *Notation*: A blue card bearing a name for one's role is used by the individual modeling participants to refer to themselves. The card is placed at the top border of the modeling surface.
- *Procedure 2.1.2*: How do I work in the course of the business process?
  - *Concept*: Modeling participants describe, what they are doing in order to complete their contribution to the business process. They describe their work by means of a sequence of distinct activities.
  - *Notation*: Each activity is represented by a red card, named by the participant to indicate what the activity is about (referred to as WHAT-item in the following). The cards are placed vertically below the blue card representing the participant's own role. Their vertical ordering indicates their sequence, the top-most card consequently representing the first activity of the participant.
- *Procedure 2.1.3*: Whom do I collaborate with in the business process?
  - *Concept*: Modeling participants determine people or roles they have to collaborate with to finish their work in the course of the business process.
  - *Notation*: For each collaboration partner, a named blue card is placed next to the blue card representing him or herself (referred to as WHO-item in the following). All blue cards are arranged along a horizontal line at the top border of the modeling surface.
- *Procedure 2.1.4*: How do I interact with others in the course of my work?
  - *Concept*: Modeling participants determine what artifacts (information, material, etc.) they exchange with others in order to complete their work. In particular, they distinguish what they require from others in order to carry out certain activities, and what they can provide to others as a result of their activities.
  - *Notation*: For each exchange, a yellow card is placed vertically below the blue card representing the respective collaboration partner (referred to as EXCHANGE-item in the following). The cards are vertically arranged to match the activities, for which the exchange is required or by which it is provided to others. Yellow cards indicating required exchanges are connected to the red cards representing the dependent activity using a arrow from the yellow to the red card. Provided exchanges consequently are indicated by an arrow from the respective red card to the yellow card.

- *Component 2.2*: Collaborative Consolidation: The following questions are not independent of each other and should be addressed in a particular sequence, which is described in detail in section "co-operation from" below. The whole component is carried out collaboratively, and is based upon the results of component 1.
  - *Procedure 2.2.1*: Who is involved in the business process
    - *Concept*: Modeling participants agree upon people or roles, who are or should be involved in the business process.

  - *Notation*: Each process participant is represented by a named blue card. The name is mutually agreed upon. All blue cards are arranged along a horizontal line at the top border of the modeling surface.
- *Procedure 2.2.2*: Who is responsible for which activities in the business process?
  - *Concept*: Modeling participants articulate, how each of them implements their contribution to the overall business process.
  - *Notation*: All activities are represented by named red cards. The name is determined by the modeling participant responsible for the activity but has to be understandable by the other modeling participants as well. The cards are placed vertically below the blue card representing the person or role responsible for enacting it. Their vertical ordering indicates their sequence in which they are enacted by the person or role. The top-most card consequently represents the first activity.
- *Procedure 2.2.3*: Who has to collaborate in which way during the business process?
  - *Concept*: Modeling participants agree upon, how to collaborate in the course of the business process and which information, material, etc. is exchanged in the course of this collaboration.
  - *Notation*: All exchanged information, materials, etc. are represented by named yellow cards. The name is agreed upon by the modeling participants involved in the exchange but has to be understandably the other modeling participants as well. Each card is placed between the source lane (i.e. the sequence of red cards headed by the blue card representing the providing person / actor) and receiving lane. If the lanes are not adjacent, the card is placed next to the lane the exchange originates from. The cards are vertically arranged to match the activities, for which the exchange is required and by which it is provided. Arrows are used to connect the red cards representing the providing and requiring activities to the yellow card.

Co-operation form

For implementing the components described above, the participants are provided with cards of different colors for modeling. The spatial arrangement of the cards based on their colors acts as a structural scaffold, guiding the consolidation process in a structured manner via dedicated areas for describing different aspects of the process (cf. Figure 4.2). Scaffolding is a concept widely used in education to describe structures or methodologies that support learners in self-directed efforts to understand something new (Van de Pol et al. 2010). The scaffold used in component 2.1 supports modeling participants in describing independently of each other their own activities, the actors or organizational entities they are interacting with, as well as how this interaction manifests itself in terms of information or artifact exchange and enables them to use the same elements for consolidation in component 2.2. Consolidation is performed according to the following scheme (modeling steps described to in brackets refer to the example depicted in the next section):

- One of the modeling participants starts by placing the WHO-item representing him/herself on the shared modeling surface. If known a-priori, the actor responsible for starting the real-world business process starts modeling (cf. step 1 in Figure 4.3). The process start is indicated by an individual model, which contains WHAT-items that are not dependent on any EXCHANGE-items to be received. If more than one such individual models exist, this indicates a business process with multiple parallel starting activities, which are only synchronized at a later point in time. In such cases, any of the affected modeling participants can start modeling.
- The same participant describes his/her own contribution to the business process by placing WHAT-items below his/her own WHO-item. Others do not intervene during this stage (cf. steps 2-3 in Figure 4.3).
- As soon as the participant places the first EXCHANGE-item (step 5 in Figure 4.3), the targeted communication partner steps in and matches his/her own perception of the business process (steps 6-8). Matching can take the following forms:
  - The communication partner has a matching EXCHANGE-item (i.e., an EXCHANGE-item that matches the already placed item). In this case, the matching elements are merged (cf. steps 19-20 in Figure 4.3).
  - The communication partner has no matching WHO-item (i.e., he/she has not perceived any collaboration with the original modeling participant at all). This is a fundamental difference in the perception of the business process. Participants need to agree, how to resolve this issue (cf. steps 15-16 in Figure 4.3, where the stock manager expected to receive a parts list from the production manager directly, whereas the production manager passed it on via the production worker).
  - The communication partner has no matching EXCHANGE-item (i.e., he/she did not share the perception of collaboration or did not consider it relevant). Such a difference again needs to be resolved by the affected participants (cf. step 22 in Figure 4.3, where the production worker considered to be finished after the order was produced, whereas the production manager expected an explicit notification that the production was finished).
  - The communication partner considers one of the his/her own EXCHANGE-items to match. The involved participants, however, have a different understanding of the content or form of the exchanged information or artifact. Such differences need to be addressed by the participants (cf. steps 5 and 8 as well as steps 11 and 14 in Figure 4.3, where in the first case the production manager provided a more detailed description of the EXCHANGE than the production worker, and in the second case the EXCHANGE between stock

manager and production worker was modified due to upfront communication of the parts list).

- Consolidation continues in this way until all points of collaboration are agreed upon. When one actor has completed his or her contribution, others with remaining elements not yet incorporated in the common model take over and provide further input to the consolidation process (cf. step 22-23 in Figure 4.3).

The limited set of modeling elements used in component 3 prevents the occurrence of co-operation and externalization problems due to lack of participants' experience in modeling (Genon et al. 2011; Britton & S. Jones 1999). When actively involving process participants, it seems to be appropriate to limit the number of available modeling elements a priori to those appropriate for the intended modeling perspective and targeted outcome (Muehlen & Recker 2008), i.e., case-based models of business processes, as in scenario-based elicitation techniques. In this way, models are kept simple and comprise the most fundamental constructs used for the description of work and therefore the first requirement of natural modeling is met ("i.e. intuitive constructs").

4.3.2.1 Example

Figure 4.2 shows three sample models created individually in component 2.1, which together form a foundation for later consolidation. The labels in the models refer to a (exemplary) production process, in which a production manager, a production worker and a stock manager are involved. The models indicate several fundamentally different understandings of how the production process should be implemented. While those differences might not occur in such a drastic way in reality, the scenario has been chosen to illustrate different aspects of consolidation below.

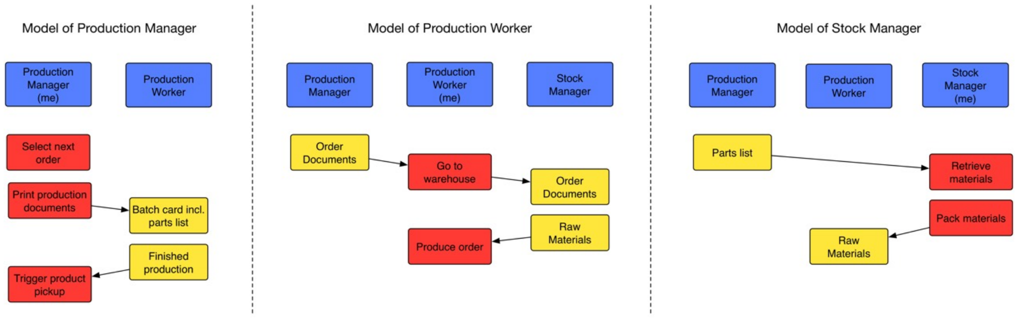

Figure 4.2: Result of component 2.1: Individual Articulation

The resulting models of component 2.1 are consolidated into a common model in component 2.2. Figure 4.3 shows the merging process for the sample models depicted in Figure 4.2. The numbering indicates the sequence of consolidation steps, the outlines of the numbers indicate the different modelers, and the stroke of the outline indicates whether conflicting viewpoints needed to be resolved.

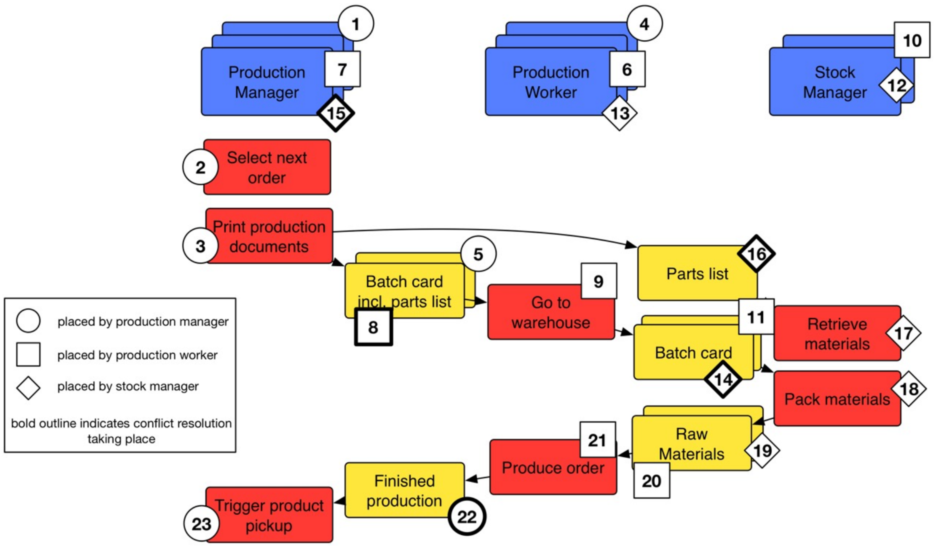

Figure 4.3: Result of component 2.2: Collaborative Consolidation

4.3.2.2 Transition from Component 1

The presented arguments for semantically open modeling in an initial phase of business process elicitation leave open the question of how the results of components 1 can be used in component 2 beyond the indirect effects caused by the upfront alignment of the participants' mental models. Although the modeling constructs are semantically not constrained in component 1, clusters of concepts that are instances of the same semantic construct can be expected to emerge during modeling (Trochim et al. 1994). Following the assumption that a business process can be described by naming the active entities, the actions performed by these entities and the exchange of tangible or intangible resources between these entities (Trochim et al. 1994), it is likely that concepts using these semantic constructs will emerge already in component 1.

Component 2.2 can be augmented by asking the participants to identify concepts from component 1, which are instances of the language constructs introduced in component 2 after consolidation. This triggers reflection on the outcome of components 1 and 2 at the same time and might lead to further modifications. Still, there might be concepts that bear semantics, which is not used in component 2. They have to be considered in the description of the process context in order to provide further information about how the model has to be interpreted and/or can be put to practice. This additional information is beneficial for model understanding of process participants (Herrmann & Nolte 2014; Santoro et al. 2010), which can be useful for refinement via virtual enactment in component 3.

4.3.3 Component 3 - Refinement via Virtual Enactment

Completing the modeling components described above leads to models that are semantically incomplete representations of business processes. Most notably, these models do not account for different variants of a business process. Refinement through virtual enactment is a means to complete a process description without the need to create comprehensive process models as in the case of traditional conceptual modeling. This is enabled by transforming the results of component 2 to BPMN (cf. Section 4.3.3.1 on transition from component 2 below) and using the BPMS described by Kannengiesser et al. (2014) and Schiffner et al. (2014) to play through complex decision processes via workflow enactment. By incrementally adding process variants, the model evolves as virtual enactment continues. Complex models of business processes are documented in this way without the need to ever translate one's perceptions of a business process to abstract process descriptions in a single step. The model permanently maintains a syntactically valid state during refinement, which allows for further processing, such as live validation of dead- or live-locks or mathematical simulation of capacities. These aspects, however, have not yet been investigated and are subject to future research.

Perspective

The method components described above deliberately follow a case-based approach to reduce model complexity and keep modeling simple and intuitive in accordance with the first principle of natural modeling. A comprehensive model of the business process, however, still is required for further processing. Component 3 therefore takes a refinement perspective on the modeling process, aiming at elaborating the model to comprehensively represent the business process. The case-based models are co-operatively refined guided by the leading question of "How should the business process be implemented to appropriately address the potentially different contexts it is executed in?"

Framework

Component 3 widens the focus of articulation from a single case, which is elaborated in component 2, to towards a comprehensive representation of the business process by elaborating the model in an interactive way. The procedures here focus on validating the model, identifying gaps and filling them with appropriate model information, if necessary:

- *Component 3*: Refinement via Virtual Enactment
  - *Procedure 3.1*: Are there any errors in how the activities and exchanges have been described?
    - *Concept*: Modeling participants identify any steps in the business process that are described in a way they consider erroneous or cannot agree upon content-wise. Such steps are modified in a way that all affected participants can agree to.

  - *Notation*: Refinement is implemented via a web-based dialogue-form, which allows to modify the descriptions of the current step.
- *Procedure 3.2*: Are there any alternative ways to act than currently described?
  - *Concept*: For each tasks the participants assess whether there are any alternative ways of acting, and, if so, under which conditions these alternatives are to be executed. Both, the additional activities and the conditions need to be specified by the affected participant and have to be understandable to all other participants, as such changes might trigger cascaded changes that need to be addressed by them.
  - *Notation*: Refinement is implemented via a web-based dialogue-form, which guides the description of deviations from the existing model, starting with deviation conditions and continuing to describe the next step.
- *Procedure 3.3*: Are there missing activities, exchanges or roles in the original description of the process?
  - *Concept*: As a result of modifications made based on question 3.2, but also due to incomplete representation in component 2, gaps might by identified in the business process. These gaps need to be addressed by agreeing on and adding further activities, exchanges or even new roles. Fundamental changes might trigger the need to go back to component 2 and explicitly address the newly identified part of the business process.
  - *Notation*: Refinement is implemented via a web-based dialogue-form, which enables the description of extensions of the existing model by adding further steps, communication acts or even new communication partners.

Co-operation form

For refinement during virtual enactment, an instance of the process is started. As stated earlier, this model initially only reflects one single variant of the process, omitting more sophisticated control flow constructs such as decisions or loops. It also does not contain the content and format of the exchanged information or resources. The aim of refinement through virtual enactment is to create a semantically correct and complete representation of the business process in all its variations as perceived by the involved actors. During the process of virtual enactment, the modeling participants enact the process step by step. For each step the responsible modeling participant assess the questions described above.

If any of these assessments lead to the need for changes in the process, these changes are made directly during execution. It should be stressed at this point that participants during the virtual enactment do not perform modeling. The BPMS rather presents web-based dialogue forms to the participants, allowing them to describe the deviations from the currently enacted process. Potential changes include adding, altering or removing activities of a process participant, shifting activities between participants, adding or removing messages required from or provided to another participant, etc. The forms support the description of the new or altered process steps by providing the current process context (i.e., what was done, before the deviation was started), as well as information about potential interaction partners.

4.3.3.1 Transition from Component 2

Component 2 has been designed to lead to models that are transformable to models created with role-aware, communication-oriented business process modeling languages such as BPMN (White & Miers 2008). If the source models adhere to the described syntax, syntactically correct models adhering to the BPMN-notation can be derived:

- WHO–elements representing actors, roles, or organizational entities (exact semantics depending on the level of abstraction individually chosen according to natural modeling principle 3) map to “pools” in BPMN.
- WHAT–elements representing activities map to “tasks” in BPMN.
- EXCHANGE-elements describing exchange of information or artifacts among WHO-elements (exact semantics depending on designator for element according to natural modeling principle 3) map to “message flow” in BPMN.

The relationships between the BPMN-elements can be derived from the spatial arrangement of the models resulting from component 2:

- Each WHAT-element is assigned to a WHO-element by placing it on an imaginative straight line originating from the WHO-element (this corresponds to assignment of “tasks” to “pools”).
- Causality between WHAT-elements is expressed by their order on the line starting with the one that is placed nearest to the WHO-element (this corresponds to “sequence flow,” “start event,” “end event”).
- EXCHANGE-elements are placed between the lines of the communicating WHO-elements and are causally related in the stream of WHAT-elements by spatial arrangement, explicitly adding connecting arrows from the activity in which or after which the exchange is triggered to the activity that receives or is triggered by the exchange (this corresponds to “message flow”).

As shown above, the proposed language can be mapped to BPMN enabling therefore virtual enactment through a BPMS.

Components 1 and 2 from a representational aspect are implemented using physical cards. In order to enable execution of the models in component 3, the card-based models need to be converted into digital model representations. To this end, the card-based model initially is captured as a pixel-based image via taking a picture, for example using a mobile phone. The modeling cards bear visual markers that can be recognized and uniquely identified in the picture. The optical marker recognition engine used for this purpose is based upon the ReacTIVision system (Kaltenbrunner & Bencina 2007). Based upon the coordinates of each marker, the cards contained in the image can be identified and extracted. The extracted information is also used for identification of potential connections that are drawn between cards. The model layout is subsequently analyzed in the next step regarding its adherence to the CoMPArE/WP notation. If modeling rules are violated, missing, or ambiguous, then the information needed for the transformation can be added interactively. IT-based guidance through the interactive parts of the transformation process is currently implemented prototypically and described in (Oppl 2015). Once the transformation process is finished, the resulting model can be used for refinement through virtual enactment.

4.4 Concept Validation

As already mentioned, the design of the CoMPArE/WP method is based on conceptual considerations derived from the aims of natural modeling (Zarwin et al. 2014). Its components are informed by procedures and concepts identified to be supportive in reaching those aims in existing research. The novelty of CoMPArE/WP lies in the combination of those procedures and concepts in order to reach the aims of natural modeling while providing a well-defined bridge towards techno-centric modeling. The goal of validation in this chapter therefore is to show that the method facilitates natural modeling and at the same time enables participants to produce a techno-centric model of the business process. Consequently, the validation questions can be derived from the design goals as formulated in the introduction: Q1) Are the modeling participants able to semantically interpret the used notation(s) intuitively in the way specified by the method?; Q2) How do the created models facilitate knowledge sharing and promote negotiation?; Q3) To which extent does the approach enable the modeling language to emerge dynamically based on the situation at hand?; and Q4) Do the final modeling results provide the syntactic and semantic quality of techno-centric models and allow for further processing in IT-systems?

These questions imply the existence of an organizational context in which actors can develop different views on a business process, calling for case study research. We thus present in the following an illustrative case study that demonstrates the implementation of the CoMPArE/WP approach in a real-worlds setting. Methodologically, the validation requires to qualitatively document and analyze both, process and result of modeling in the different method components with respect to the formulated questions. Consequently, the modeling process of the case study was video taped and analyzed with respect to the validation questions asynchronously. The modeling results of component 1 and 2 were photographed and transcribed to digital versions for easier assessment. The results of component 3 were exported from the used BPMS. The documented results and observations made in the case are used to discuss how the requirements of natural modeling are met while maintaining the bridge towards a technically interpretable business process model.

4.4.1 Illustrative Case Study: The project set-up process

The case presented in the following is situated in an organization that undertakes software development projects. At the beginning of every project, the project set-up process is conducted aiming at agreeing upon the project's scope, the relevant stakeholders, the timeframe, etc. The project teams always consist of a set of developers, who are led by a team leader. Ongoing communication with the client is ensured by a dedicated contact person (who, might also be a developer). In addition, there are mentors who formally do not belong to the team, but are experienced project managers supporting the project teams and acting as backups, if interventions become necessary.

The aim of the CoMPArE/WP workshop was to investigate the effectiveness of the CoMPArE/WP approach regarding a) the active involvement of process participants in business process design and b) the transition to a comprehensive process model. Representatives of the following roles took part in the workshop: a team leader, a mentor, the contact person, and a client. In addition, a facilitator was involved to guide the process methodologically. One observer was present to document the results and the process of the workshop for later evaluation. The workshop was carried out in two parts. The first 3-hour block was dedicated to the first two components of CoMPArE/WP. Based on the outcomes of this first part, a model was built using the CoMPArE/WP language (based on the *who*, *what*, *exchange* constructs). This was used for virtual enactment in the second part of the workshop, which lasted 2 hours.

4.4.1.1 Component 1: Setting the stage

The four modeling participants implemented the first component of CoMPArE/WP by creating a model that described the relevant concepts in the context of clarifying the scope of a new project. They followed the procedure described above, i.e., individually collected concepts each of them considered important and subsequently consolidated them in a shared model.

The identified concepts were complementary, as the modeling participants focused on different aspects of the business process. Consolidation consequently required effort in making mutually transparent the individually selected foci and explaining their meaning. However, no discussions on the relevancy of certain concepts arose, and all concepts were finally incorporated in the model.

Figure 4.4 shows a conceptualized transcript of the model. On the right, a photo of the workshop's real card setting is presented. As shown in this photo, the cards bear the visual markers for digital recognition mentioned earlier. Also, a big table constituted the sharing modeling surface and thus connecting arrows were drawn directly on the cards.

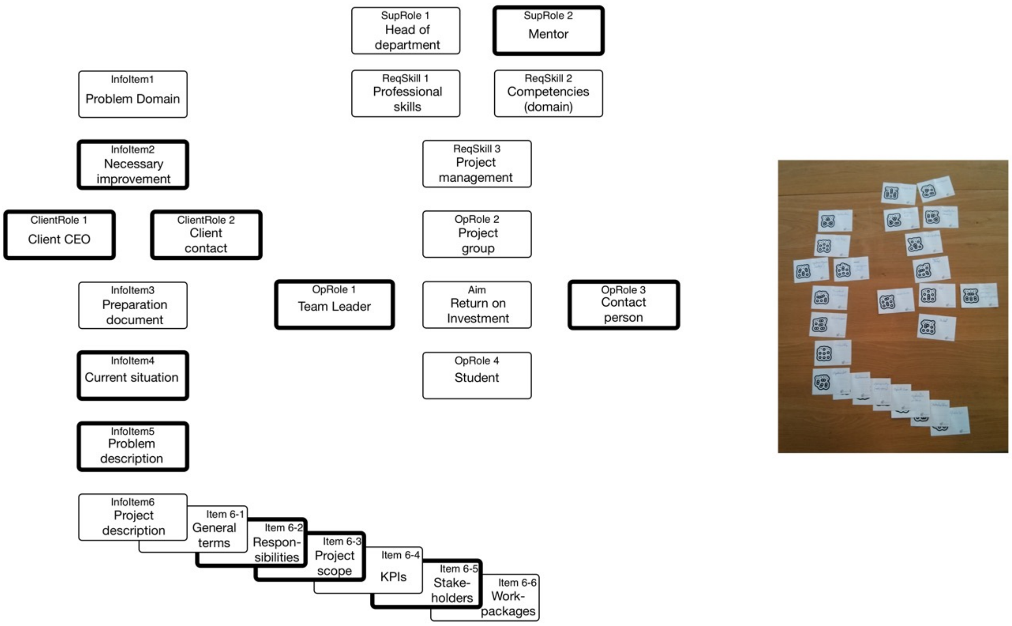

Figure 4.4: Result of Component 1 - "Setting the stage"

The identified concept classes largely centered around the different involved roles (operative in the project team - *OpRole* -, as well as roles that support the process within the organization -*SupRole* -, and client-side roles - *ClientRole*) and relevant information items (*InfoItem*) that were backed with sub-items in the case of the project description (visualized at the bottom of Figure 4.4). In addition, skills required within the project team (*ReqSkill*) as well as the aim of the process (*Aim*) were identified.

The concepts were clustered along two dimensions: the sequence of elements running from top left to the bottom right of the model indicating the fundamental procedure of clarifying the project scope with the customer. It thus can be considered to represent an "external perspective" on the project setup process. The ostensible sequence in the first cluster, however, does not describe a process, as it does not rely on activity-describing concepts, but mixes other, structurally motivated concept classes. The second cluster of concepts can be considered to cover the "internal perspective" on the project setup process and has identified the necessary skills and involved operative and support roles.

The open semantics used in this component enabled both – the agreement on relevant conceptual classes (like aims, skills, roles and information items) and their clustering in terms of perspectives to be considered when thinking about the business process for project setup (internal needs vs. externally visible collaboration and artifacts). The elements marked with bold outlines were directly re-used in individual articulation and subsequently were incorporated in the consolidated model version. The remaining elements (drawn with narrow stroke outline) were not incorporated in the following steps but left as contextual information, describing the context of the process.

The outcome of the first modeling step thus clarified the scope of the business process to be reflected upon and outlined its fundamental building blocks. It furthermore validated the selection of the involved roles. Consequently, concepts specified in the first component were re-used in later modeling steps indirectly by the modeling participants, who picked them up again during individual articulation.

4.4.1.2 Component 2.1: Individual articulation

In the second component, the modeling participants individually described their own perceived involvement in the business process and their interaction with others. The individual modeling results are shown in the following. As the connecting arrows were drawn directly on the cards, explicit representations of sources and targets in communication acts have been added in the conceptual transcriptions for easier understandability.

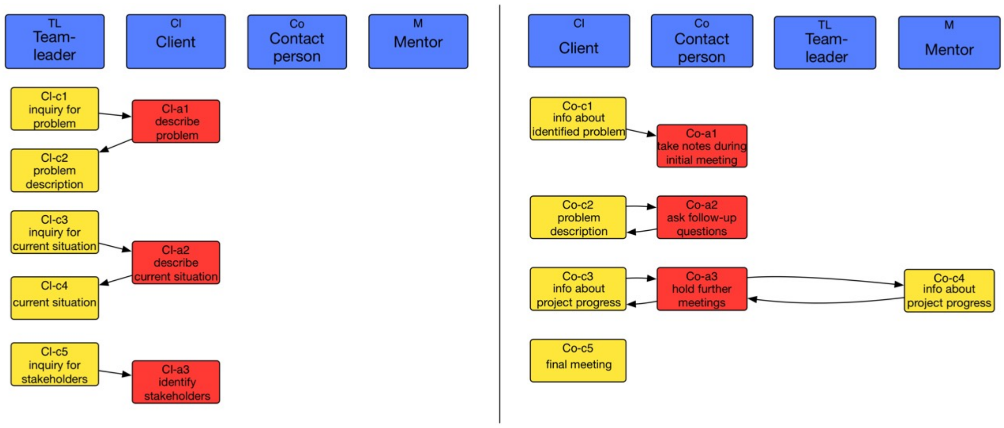

Figure 4.5: Result of Component 2.1 - "Individual Articulation" for participants representing "Client" (left) and "Contact Person" (right)

Figure 4.5 (left) shows the model created by a modeling participant representing the client. Content-wise, one notable modeling choice here is the strong involvement of the team leader in communication, while at the same time communication with the formally responsible contact person is completely omitted.

The perceived involvement of the contact person is shown in Figure 4.5 (right). The modeling participant representing the contact person basically described the formally prescribed procedure of acting as the primary contact for the client and involving the mentor during project implementation, after the problem description has been settled upon.

The model incorporates a syntactic deviation from the proposed modeling language as EXCHANGE elements were used to describe mutual communication processes. The proposed syntax defines EXCHANGE elements to always have exactly one source activity and one target activity, representing a uni-directional flow. In terms of natural modeling, however, this is a valid use of the element as it takes a coarser approach to describing exchange of information, which can be refined in later steps when developing towards a model that is useable for workflow execution.

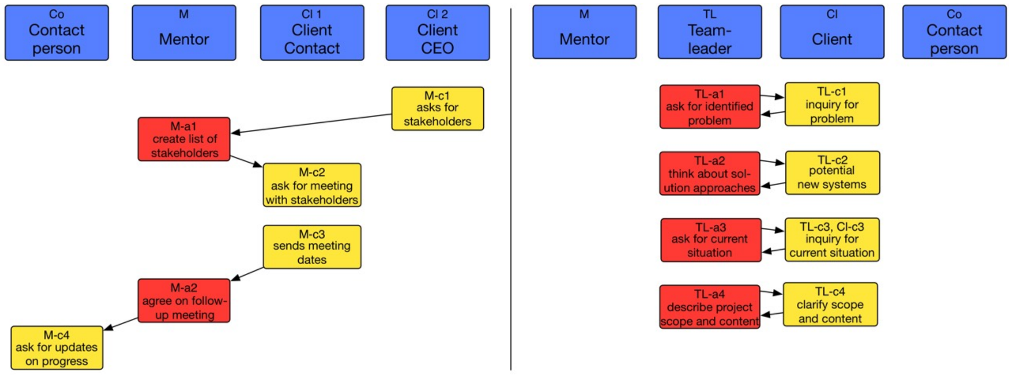

Figure 4.6: Result of Component 2.1 - "Individual Articulation" for participants representing "Mentor" (left) and "Team Leader" (right)

The model shown in Figure 4.6 (left) represents the mentor's view on the business process. It describes an intervention in the late stage of the scope clarification, where the mentor communicates with a management representative of the client and the operative contact regarding relevant stakeholders in the client company and then agrees on a follow-up meeting during the project with the customer contact person in the project team. The mentor was the only modeling participant, who distinguished between different client roles.

The fourth individual model shown in Figure 4.6 (right) represents the team leader's view on the business process. It largely matches the view of the client, in which the main tasks of project setup are shared by the two of them – in contrast to the company-wide guideline, which stated that the contact person should be the sole face to the client. Structurally, the model contains bi-directional exchange attached to single activities, like in the model of the "contact person". As above, the participant was not able to describe a more detailed interaction process for his perceived tasks and thus – as proposed in principle 3 of natural modeling – dynamically adapted the modeling language to be able to represent his perceptions.

Overall, individual articulation lasted around 30 minutes and was carried out without any communication between the modeling participants. The facilitator intervened methodologically once in clarifying the meaning of EXCHANGE elements for the person representing the customer contact. The other modeling participants did not have any issues with understanding and using the modeling elements according to their description.

4.4.1.3 Component 2.2: Collaborative consolidation

Figure 4.7 shows the agreed upon card-based model of the business process of the collaborative consolidation. Figure 4.7 uses the same unique identifiers for elements as specified in the individual articulation models. The only element that has not been incorporated in the shared model was "Co-c5" (final meeting). This EXCHANGE-element was agreed during collaborative modeling to be superficial, as it was beyond the scope of the business process. Some elements have been added, mainly to reflect the activities of the originally underestimated role of the team leader. Added elements bear labels starting with "N". In the following, we describe the changes made during consolidation and outline their rationale as given by the modeling participants (extracted from workshop recordings).

The consolidated model shows the business process from an overall perspective. In a collaborative effort (cf. natural modeling principle 2), the modeling participants reached common ground on the issue of who should be the primary contact to the customer during project setup. The modeling participants followed the argumentation of the client representative, who claimed that it was crucial to involve the team leader in the early phases of a project to create a clear and unbiased image of the client's needs. Consequently, the role of the customer contact was reduced to acting as a supporter for the team leader during the project setup phase and only taking over operative communication after the successful kick-off of the project. The modeling participants also recognized the need for phases of intense communication between the team leader and the client, which is indicated by the double-linked EXCHANGE-elements "TL-c4" and "TL-c2". Following the argumentation of the team leader, the other modeling participants also refrained from detailing the communication any further and identifying distinct acts of information exchange in those phases. The same holds true for the communication between the mentor and the customer contact at the very bottom at the model (indicated by the matched and merged EXCHANGE-elements "Co-c4"/"M-c4"). Additions to the model (all elements with Prefix "N") were added by the modeling participants representing the affected roles. In all four cases this was triggered when they were confronted with EXCHANGE expectations of communication partners they could not meet with existing WHAT-elements.

The CoMPArE/WP-methodology should lead to pair-wise matching EXCHANGE-elements, one element representing provided EXCHANGE created by the sender and one representing expected EXCHANGE created by the recipient. This matching, however, was only done three times (for EXCHANGE-elements "TL-c1"/"Cl-c1", "TL-c3"/"Cl-c3", and "Co-c4"/"M-c4"). The lack of further matches can be attributed to the role shift in interaction with the customer, which was not reflected in the individually articulated models of the customer contact person and the mentor. In addition, the EXCHANGE-elements M-c2 and M-c3, originally targeted at the client in the individually articulated model of the mentor were not matched by the client in the consolidation phase. The representative of the client was not able to describe a WHAT-element that would have been triggered by M-c2 and would have led to issue M-c3, and thus left those two EXCHANGE-elements dangling. This leads to temporary under-specification of the model, which causes issues that need to be resolved during virtual enactment.

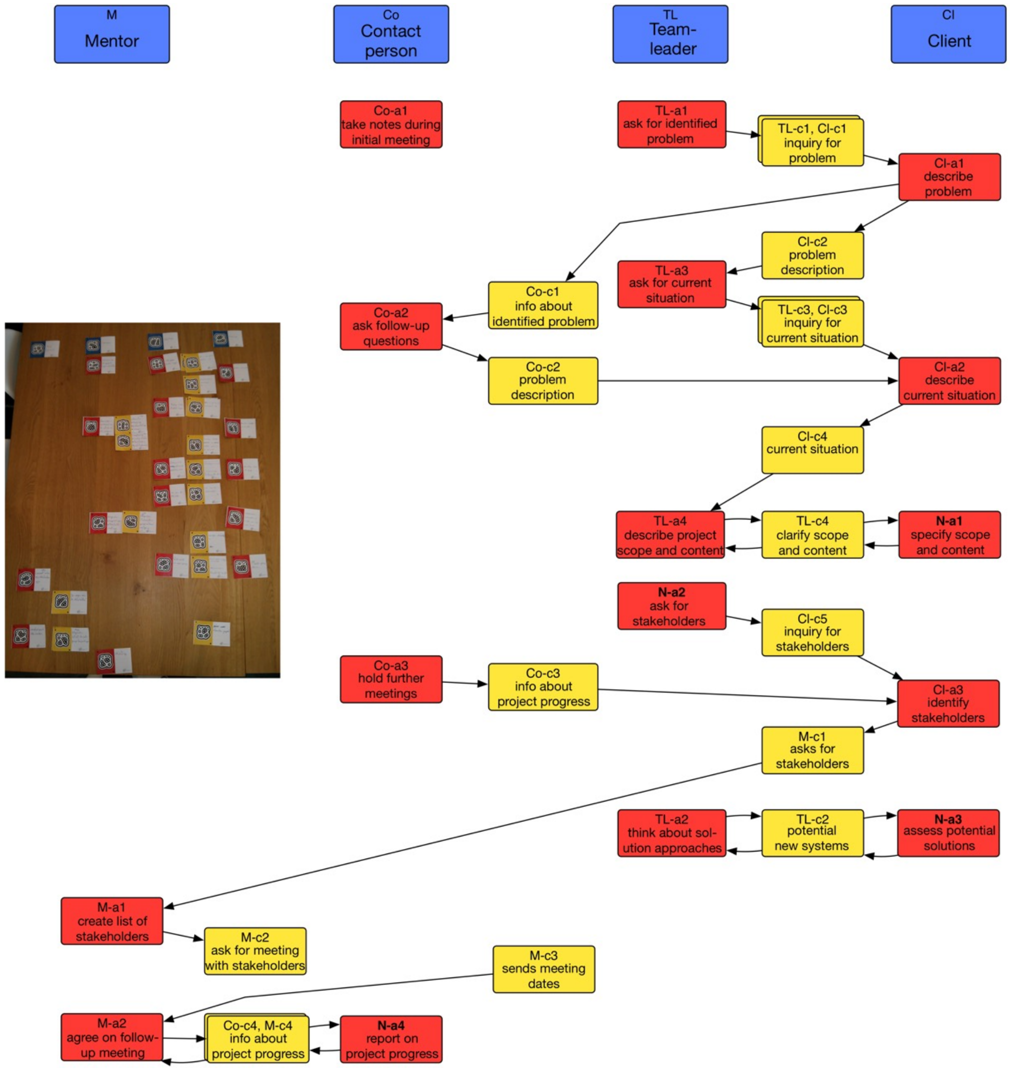

Figure 4.7: Result of Component 2.2 - "Collaborative Consolidation"

In a final step, the results of component 1 ("Setting the stage") were reflected against the outcome of collaborative consolidation. Regarding constructs, the participants were not able to match the concepts describing skills and the aim of the process. These concepts were left aside for later consideration.

As far as content is concerned, the participants discussed the concepts representing roles and information items. They were able to confirm semantic equivalence to WHO and EXCHANGE items, respectively: "Team Leader", "Contact Person" and "Mentor" were directly matched. "Client CEO" and "Client contact" were only used as separate items in the mentor's individual articulation, whereas all other participants only worked with a single "Client" element. During reflection of collaborative consolidation, this issue was addressed again. The participants used a single client element in the consolidated version, as they agreed that distinguishing between the Client CEO and Client contact was not necessary and relevant for the depicted scenario. “InfoItem5 - Problem description” was directly reused in component 2 as “Co-c2”, “Infoitem4 – Current situation” was reused as “Cl-c4”. Other InfoItems were identified during reflection to be semantically equivalent: “InfoItem2 - Necessary Improvement” was matched to “Co-c1”, “InfoItem6-2 – Responsibilities” and “Infoitem6-3 – Project Scope” were covered by “TL-c4”, and “Infoitem6-5 – Stakeholders” were subject of modeling in the sequence stating at “N-a2” to “M-a1”. The remaining concepts that were considered to be potentially relevant during component 1 have not been incorporated in the result of component 2. They were still considered relevant for understanding the business process and consequently remained as context information.

4.4.1.4 Component 3: Virtual enactment

For virtual enactment, the model was transformed to a syntactically correct BPMN model (cf. Figure 4.8). The source model has some semantic ambiguities that hamper direct enactment, as the BPMN model is semantically underspecified.

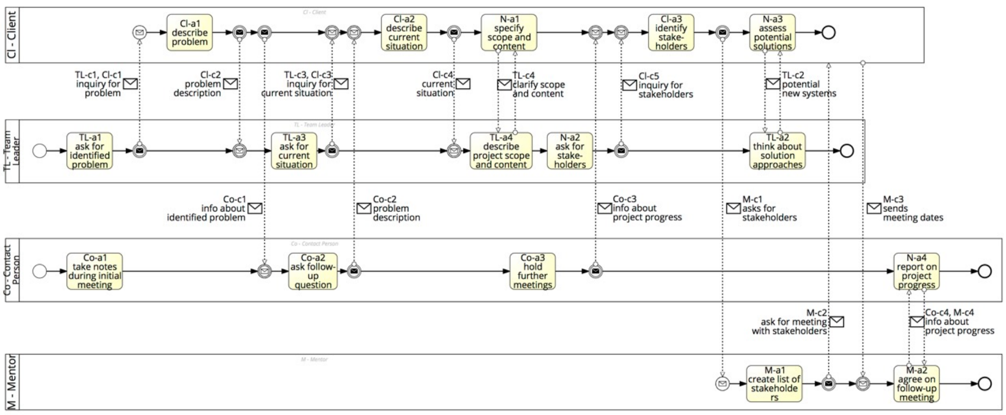

Figure 4.8: Result of transformation to BPMN

The affected elements are “TL-c4”, “TL-c2”, and “Co-c4”/“M-c4”, where the exact point in time of EXCHANGE is not specified. In addition, “M-c2 and “M-c3” are not explicitly considered by the client for receiving and sending, respectively, at all. Consequently, the first group of ambiguities was transformed to mutual message flows connected to the respective activities, whereas the second group of messages was transformed to message flows that are connected to the targeted pool representing the client. All other exchange elements were mapped to message flows with corresponding throwing and catching message events.

This model was used for virtual enactment to identify necessary refinements and extensions of the process model. This was done in a second workshop, in which also a representative of the team leader role was involved. As an example for refinements through virtual enactment, Figure 4.9 shows the initial refinement step made in the workshop, visualizing the original version of the team leader’s behavior on the left and the refined description of the behavior on right. The elements bearing a name starting with “R” have been added during refinement. The refinements in this step do not affect any other pools, thus no cascading changes were necessary.

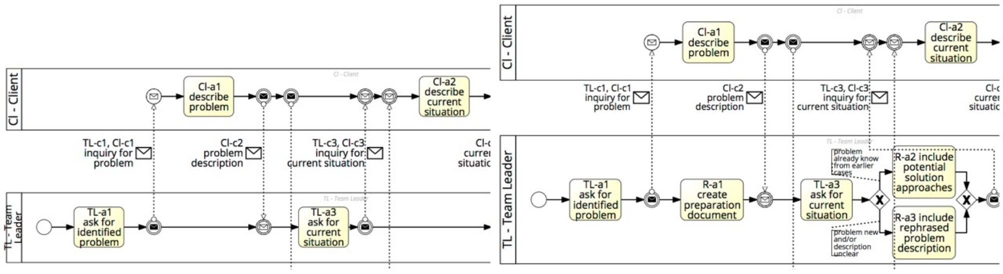

Figure 4.9: Example of refinement (left: original process, right: refined process)

In the later phases of virtual enactment, the semantic ambiguities still contained in the model were resolved. For “TL-c4”, “TL-c2”, and “Co-c4”/“M-c4”, a more detailed description of the communication procedure (to be implemented in future) was created, whereas “M-c2 and “M-c3” were removed, reducing the mentor’s role to an internal one, only interacting with the client contact person and the team leader. In making these changes, the model gradually evolved from depicting the as-is-process to depicting a to-be-process, envisioning improvements to the collaboration setup via playing through the process model. The case study was concluded after this first iteration through the modeling and virtual enactment process.

4.4.2 Discussion

The following discussion of the evaluation results is structured along the validation questions formulated above. The section closes with a summary.

Q1 – Intuitiveness of modeling: Ex-post feedback of the workshop’s modeling participants revealed that they enjoyed their engagement in process modeling. They felt that they had generated added value for their understanding of the business process itself and how it is embedded in the process landscape of the organization. In the case study, the incremental rise in the modeling language complexity throughout the phases in particular helped the inexperienced modelers become familiar with reading and understanding models, and using them as a form of expression for their own viewpoint, facilitating in this respect the externalization of tacit knowledge. Tangibility of the modeling elements (i.e., their physical presence in the form of cards and the chance to directly manipulate them) seemed to have positive impact on the “intuitiveness” of the modeling process itself. One participant in the case study, agreed by the others, stated that “not having to master a computer tool before being able to contribute” provided added value over more traditional computer-screen-based means of modeling support.

Q2 – Facilitation of knowledge sharing and negotiation: The process of modeling and refining the model through virtual enactment is inherently cooperative in all its components, which have been successfully implemented to this respect in the case. Alignment of concepts and constructs in particular has been facilitated in the second component, which by design focuses on uncovering ambiguities and different perceptions and facilitates the development of a shared understanding. The fundamental content-wise revisions of the business process during collaborative consolidation in contrast to the individually created model parts is an indicator that knowledge was not only successfully shared among the modeling participants but also has been actively co-constructed via negotiation processes. This observation is confirmed by results of further studies of a variant of this component reported on in (Oppl 2016d).

Q3 – Emergence of modeling language semantics: During concept mapping applied in component 1, the used language constructs emerged fully dynamically during modeling. In component 2, the set of language constructs was more restricted, but still left room to adapt to the situation at hand due to their abstract nature. The modeling elements used in component 2 (WHO, WHAT, EXCHANGE) were intuitively used correctly (i.e., according to their prescribed semantics). A drawback of the reduced set of modeling elements, however, became apparent during collaborative consolidation. The lack of a structured approach to specify the content of EXCHANGE elements led to “vague” definitions (Herrmann et al. 2000) that neither reflected nor facilitated the achievement of agreement on the transferred information or artifacts. This, however, could be compensated for during virtual enactment, when the resulting “vague” message flows were refined with scaffolds provided by the facilitator.

As it can be seen in the case description, nearly half of the concepts identified in component 1 were reused in component 2 as a foundation for individual articulation and for collaboratively reflecting on the outcome of consolidation. The benefit of open semantics as used in component 1 is that it makes visible how to reconcile fundamentally diverging viewpoints on the scope of the process and the vocabulary used to describe it. Both issues were hardly present in the case study, so that the added value of component 1 was to confirm the already shared understanding of what the project setup process was about and to produce an artifact that later could be used for reflection of the process modeling results.

Q4 – Evolution of techno-centric models: The model resulting from component 2 semantically depicted a single scenario of the complete process and was syntactically compatible to BPMN. The transformation process led to a model that already met the aim of producing a syntactically correct business process model. This model was then used for semantic refinement through virtual enactment in component 3. Only at this point, a semantically fully refined modeling language (BPMN) was used for representing the process. During virtual enactment, the participants, however, were not directly confronted with the BPMN model representation, but performed refinement by describing their additional or altered process steps in the BPMS. The process of refinement, however, was perceived to be cumbersome due to the lack of appropriate tool support in the prototype. Participants had difficulties to appropriately describe their additional process steps appropriately, in particular when additional message exchange was required. Picking up sent messages on the receiving side was confusing for the participants, as the user interface did not appropriately guide them to resolve such temporary process inconsistencies. These situations were resolved by the facilitator but require further research and development.

Summary: According to our overall experience acquired through the case study, the method has succeeded in implementing the principles of natural modeling and has achieved to actively involve process participants in modeling leading at the same time to the production of a BPMN-model, which can act as the basis for further techno-centric processing. The case study, however, also illustrated challenges in the design process, in particular at the gateways between the methodological components. The role of a facilitator still appears to be of high importance for guiding through the articulation and consolidation process. The major challenge here seems to be prompting participants in a way that facilitates description of their work so that the semantics of BPMN elements the model is transformed to later on is accommodated. This has not been fully successful in the described case, which caused higher effort during transformation to BPMN. Facilitator's guidance appears also to be required for applying correctly the modeling guidelines. It is notable that participants failed to correctly refine the labels of the EXCHANGE elements, after their transformation to BPMN message flows for use in component 3. In component 2, they partially used verbs instead of nouns that are normally used to indicate exchanged messages in BPMN and were not aware of the need to change this until an intervention of the facilitator.

4.5 Related Work

CoMPArE/WP is based on the idea of participatory design. This is also the foundation of the work of Türetken & Demirörs (2011), who propose a decentralized process elicitation approach ("Plural") in which individuals describe their own work. Plural is based on a multi-perspective modeling paradigm (Mullery 1979), which focuses on representation of individual work contributions in models and subsequently merges them into a common model by agreeing on the interfaces among the individual models. It uses eEPC (Nüttgens & Rump 2002) as a modeling language and assumes that actors are familiar with this (techno-centric) language. Plural uses tool support built upon a commercial modeling environment, which identifies inconsistencies between individual models. The authors mention tool support for resolution of inconsistencies between models but do not elaborate further on how scaffolding for inexperienced modelers could be implemented.

Multi-perspective modeling is also proposed by Front et al. (2015) in their ISEA approach to involve process participants in business process elicitation. Perspectives here are with respect to different constructs used to describe organizational reality (which is different to PLURAL and CoMPArE/WP, where multiple users conceptually describe their perspective on organizational reality using the same constructs). Similar to CoMPArE/WP It emphasizes the needs of process participants for a "simplified domain-specific language", which, at the same time is kept executable to allow for interactive validation through roleplays. While the intended outcome of the method is similar to that of CoMPArE/WP, the methodological focus of the two methods is different. ISEA focusses on eliciting business process models by reviewing them from different semantic perspectives, while CoMPArE/WP focuses on methodologically supporting the identification and resolution of different viewpoints in terms of construct semantics and collaboration when implementing a business process.

Herrmann et al. (2000) have also adopted the idea of participatory design for process elicitation proposing a methodology ("Socio-technical walkthrough" – STWT) that allows the creation of semi-structured and incomplete models. Workshops following the STWT methodology (Herrmann et al. 2007) target domain experts who do not necessarily need to have modeling experience. The STWT uses SeeMe (Herrmann et al. 2000) as a modeling language, which comprises three core-modeling elements with context sensitive semantics and is designed to represent models of socio-technical systems. It represents vague information, which explicitly captures disputed or unclear parts of a business process and thus is very close to the principles of natural modeling. No explicit scaffolds for model creation or alignment, however, are embedded in the methodology or the modeling language. The resulting models are intended for use in information system design but are not executable in BPMS. A similar approach is proposed in CPI modeling (Barjis 2011). Modeling is performed in a workshop setting similar to the STWT and focuses on validation of the process during modeling by revisiting the model concepts in moderated discourse. The approach claims to use an intuitive modeling language, which appears to be a simplified version of activity diagrams, to let process participants collaboratively create a "trustworthy and complete" model of an enterprise. Again, the focus is on process elicitation and no bridge towards execution of the created models is discussed. In an attempt to make BPMN (as a techno-centric language) more accessible for participatory design by process participants, T-BPM (Luebbe & Weske 2011) use tangible modeling elements in a collaborative workshop setting. The modeling methodology focuses on articulation using BPMN notation elements, which, the authors claim, are intuitively understandable by participants after a brief introduction using examples. The result of modeling can be manually transcribed to a digital representation for further processing.

CoMPArE/WP in its final component provides tool support for guiding collaborative model creation among participants. This approach is also promoted by COMA (Rittgen 2009b) and CEPE (Santoro et al. 2000). COMA focuses on providing support for articulating and consolidating models during collaborative modeling with a language-agnostic negotiation approach. The COMA tool provides support for UML (Unified Modeling Language) and enables actors to communicate via the software in a structured way specified by the COMA methodology. It provides scaffolds for model consolidation (i.e., the negotiation process), but presupposes that the involved participants are technology-proficient. As a result, participants, who have an important input to a process but do not feel comfortable with such software tools might express unwillingness to be involved in a software-based collaborative elicitation-modeling procedure. CEPE also supports collaboration during modeling with a particular focus on BPM. The modeling language proposed uses a limited set of elements to describe tasks, responsibilities, and decisions in a process. Further technical processing of the resulting models, however, is not addressed. The associated tool provides awareness features that support collaborative modeling. Aside of these features, no dedicated methodological or conceptual support for collaboration of process participants is provided. In more recent research, Santoro et al. (2010) propose to use storytelling techniques in the early phases of process elicitation and further develop these stories to BPMN models of the described process. They describe a method to support the abstraction process necessary to derive models from stories and to finally create formal representations in BPMN. As such, it takes a complementary approach to CoMPArE/WP, where the need for explicitly creating formal representations is avoided by refinement via virtual enactment.

Table 4.1: Review of Related Work

	Q1 - Intuitiveness of modeling	Q2 - Facilitation of knowledge sharing and negotiation	Q3 - Emergence of modeling language semantics	Q4 - Evolution of techno-centric models
Plural		multi-perspective modeling		uses processable eEPCs
ISEA	via simple domain-specific languages	multi-perspective modeling		
STWT	via simple notation and vagueness	collaborative workshop	through combination of elements and vagueness	
CPI	via simple notation	collaborative workshop		
T-BPM	via tangible elements	collaborative workshop		uses processable BPMN
COMA		tool support for negotiation		uses processable UML
CEPE		tool support for awareness		
Storytelling for BPM		collaborative workshop	non-restricted semantics during storytelling	

Table 4.1 summarizes the characteristics of the described approaches with respect to the validation questions specified above. As can be seen, CoMPArE/WP is not the first approach to tackle collaborative modeling by process participants for eliciting business process knowledge. Existing approaches supporting collaborative articulation and modeling, however, either target inexperienced modelers or aim at producing a model that can be directly executed. This is a reasonable approach given the conflicting requirements in those areas (Zarwin et al. 2014). From a BPM perspective, however, it remains desirable to satisfy requirements in both areas with a single methodological approach. The present work goes beyond the state-of-the-art by proposing a methodology that involves transitioning from natural modeling toward refinement of technically interpretable models. To enable this transition, the representation used for articulation and alignment support is syntactically and semantically compatible with techno-centric modeling languages like BPMN.

4.6 Conclusion

The approach presented in this chapter aims at actively involving participants in business process modeling to enable real integration between elicitation and modeling steps of the BPM lifecycle. Active involvement of process participants creates several challenges, as the latter are not expected to have modeling skills, and thus require facilitation for elicitation and formulation of the models in a way that allows for technical processing of the results. The CoMPArE/WP approach meets successfully this goal by operationalizing the principles of natural modeling while at the same time providing a transition to a representation of a business process that can be enacted by a BPMS. As also revealed by the case study, the gateways between the methodological components constitute the major challenge in the application of the approach. CoMPArE/WP has tackled this issue by introducing a simple intuitive modeling language (consisting of the fundamental process concepts *who*, *what* and *exchange*) that bridges the gap between the human-oriented card-based model of the first components, which uses open semantics and the techno-centric process model created in the last component. The approach enables participants to gradually develop structured business process models and does not confront them with the complexity of fully elaborated process models. While the transparency of the complexity of the developed model has been a design goal, it can be at the same time considered the most fundamental disadvantage of the approach, as it prevents to develop an in-depth understanding of the resulting process model by the modeling participants. Furthermore, the elicitation strategy of the methodology is focused on the individual perceptions of the business process contributed by the participants and does not consider potentially divergent process views of other stakeholders, which are not directly involved in the modeling process.

The present work has several methodological limitations. First, the validation is limited to a single case, and consequently is restricted in scope, application domain and complexity. Still, the feasibility of the proposed method is demonstrated and the identified shortcomings hint at areas of further improvement. Second, the method component "refinement via virtual enactment" has not yet been examined in full consequence. The case did not provide the opportunity to assess the viability of the approach in case of fundamental changes such as the introduction of an additional actor. While the conceptual and technical means to implement such changes are available, their usability in terms of the methodology remains to be examined. Third, results from research conducted in parallel with the present work in the field of multi-perspective end-user modeling (e.g., (Front et al. 2015; Simões et al. 2016)) could provide relevant input for further improving the method with respect to supporting natural modeling. These results, however, have not yet been incorporated in the work reported on in the present chapter.

Our future work consequently will mainly focus on the methodological and technical implications of a (semi-)automatic transition from natural modeling settings to processing-oriented business process modeling. This requires further empirical evidence in particular on the participants' expectations and requirements at the gateways between the different methodological components. Evaluation setups that go beyond participatory observation are necessary to enable a structured review of the transformation steps of the models between the different components and how they affect the resulting business process models. The findings from these evaluations will further refine both the methodology and the supporting tools. Future iterations will focus on improving technical support for refinement through virtual enactment (e.g., providing interactive scaffolds for modifications of the model) and for the model transformation process (e.g., merging of multiple models produced during iterative consolidation).

5 Evaluation of collaborative modeling processes for knowledge articulation and alignment[1]

5.1 Introduction

Examining the process of conceptual modeling is an area of research that has gained momentum in the last years (Claes et al. 2013; Soffer et al. 2012). Research in the area of process management traditionally has taken the existence of appropriate models for granted (Hjalmarsson et al. 2015), and has hardly addressed the questions of how models should be created, who should be involved during creation, and how an appropriate representation of the real world could be assessed.

Over the last years, however, interest has risen in researching the facilitation of the process of model elicitation and creation (Hjalmarsson et al. 2015). One notable trend in this area is the active involvement of domain experts in the modeling process (Antunes et al. 2013). This strategy is based on the hypothesis that direct involvement of people with relevant knowledge can help to avoid modelers' bias and consequently lead to models that are more useful for informing actual work processes (Krogstie et al. 2006). End-user involvement has been successfully pursued in the area of requirements engineering (Mullery 1979) and educational research (Mayer 1989) since decades. It also has been deployed in several research efforts in the area of social-technical systems modeling (Herrmann et al. 2000). Approaches following this strategy, however, usually have adopted measures related to the generated outcome to assess their impact and hardly have evaluated the process of modeling itself.

In recent years, it has been recognized that the added value of domain-expert-driven modeling not only is generated via the resulting models, but also by creating common ground for the involved people (Hoppenbrouwers et al. 2005). Research has started to examine how facilitation of modeling processes can support the evolution of

[1] This chapter is identical in terms of content to the accepted final version of the article „Oppl, S. (2016). Evaluation of collaborative modeling processes for knowledge articulation and alignment. Information Systems and E-Business Management, in press. http://doi.org/10.1007/s10257-016-0324-9“. It has been modified to provide consecutive numbering of sections and figures throughout this thesis.

common ground (Hoppenbrouwers & Rouwette 2012). In this line of research, several efforts have been made to qualitatively describe the effects occurring during modeling (Rittgen 2007; Seeber et al. 2012). The modeling process is considered as a series of negotiation acts among actors, with the model being an artifact generated as an outcome. Evaluations of the process of modeling consequently focus on depicting and analyzing the observed negotiation acts and their impact on the model. Other approaches focus on the process of model creation and collect their data solely from observing the manipulation of the model (Pinggera et al. 2012; Sedrakyan et al. 2014).

As will be shown in more detail in Section 5.2, these approaches examine different aspects of how the actors negotiate to reach a common understanding about content of the model. Existing research (Gemino & Wand 2003; Krogstie et al. 2006; Mayer 1989) indicates that further potential for evaluating collaborative modeling processes can be found in examining an actor's understanding about a modeled topic and how this its development is facilitated during modeling. These works argue for the need of assessing the development of understanding about the modeled topic, as the understanding of a topic ultimately affects the actions performed in the real world. Several authors have addressed this issue from a cognitive perspective, focusing on the development of understanding on the subject of modeling for individual modelers (Claes et al. 2015; Recker et al. 2013; Soffer et al. 2012). They, however, either focus on examining the modeling process of individual modelers confronted with artificial tasks in an experimental setting (Claes et al. 2015; Soffer et al. 2012) or examine collaborative modeling processes ex-post using questionnaires (Recker et al. 2013). The process of collaborative modeling itself not yet has been investigated with respect to how the involved actors articulate their individual views about the modeled topic and how they develop a common understanding.

This chapter introduces an approach that addresses this gap and considers collaborative modeling as a process of knowledge articulation and alignment. We adapt an evaluation methodology that has been proposed in the area of technology enhanced learning (Weinberger & F. Fischer 2006), where articulation and alignment has already been adopted as a perspective when evaluating collaboration processes. Taking this perspective on evaluation allows to fill the gap identified above. A comparative field study has been conducted for comparing the proposed methodology with other evaluation approaches identified in related work as a baseline to show that it allows to derive information previously not addressed in data analysis. The results of the field study are also used to discuss the implications of using diverse objects of investigation to analyze complementary aspects of a collaborative modeling process.

This chapter is structured as follows: In the next section, the current state-of-the-art for evaluating collaborative process modeling processes is presented. The chapter reviews those approaches regarding the information that can be drawn from their results for assessing modeling techniques and identifies a gap in the current state-of-the-art. It then introduces an evaluation approach, which investigates the process of collaborative modeling from a knowledge articulation and alignment perspective. Subsequently, this approach is reflected against existing approaches by applying them on a real world case and assessing the qualities of the different outcomes. The chapter closes with the discussion of the implications of these findings and an account on the next steps towards a comprehensive evaluation framework for collaborative modeling processes.

5.2 Related work

The empirical analysis of conceptual model quality has been subject of research for more than two decades (Sindre et al. 1994). Based on an extensive literature review, Gemino & Wand (2004) derive a framework for empirically evaluating conceptual modeling techniques. Their analysis shows that most approaches use the modeling results as their objects of investigation and omit the process of modeling itself. This diagnosis remains true also in more recent research (Nelson et al. 2011; Claes et al. 2013). In this light, Gemino & Wand (2004) propose to also to assess the effectiveness of the process of model creation and model interpretation. While they identify potential useful variables, they do not address the operationalization of these variables.

This prior research has been picked up in the emerging research field of collaborative modeling in recent years (Mendling et al. 2011; Wilmont et al. 2013). When focusing on collaborative aspects of modeling, the process of model creation and understanding is intertwined, as different actors dynamically switch between active and observational roles during the process of modeling. The observable interaction phenomena thus are an important aspect of evaluation.

The empirical analysis of the process of collaborative modeling has been addressed in various disciplines, from system dynamics (Rouwette et al. 2002) over requirements engineering (Konaté et al. 2013) to process modeling (Rittgen 2007). In the area of collaborative problem solving, existing research has proposed approaches to describe social processes that can be observed during collaborative work (Weinberger et al. 2007). Those approaches are not limited to collaborative modeling tasks. In the following, we focus on approaches that have been applied in a modeling context.

5.2.1 Available approaches for evaluating collaborative modeling

Rittgen (2007) proposes a coding scheme to describe negotiation during collaborative modeling sessions. The analysis is based on utterances of the actors make during the modeling session collected using a think-aloud methodology (Van Someren et al. 1994). The utterances are analyzed along “levels of organizational semiotics” (social, pragmatic, semantic, and syntactic level. These levels allow to describe a modeling process regarding the interaction among the modelers from different perspectives - regarding their collaboration (social, pragmatic) as well as how they build a model about their topic of discourse (semantic, syntactic).

This approach has been adopted by Seeber et al. (2012) to investigate collaboration in group settings and develop support for such evaluations in the CoPrA toolset. They use the pragmatic dimension of Rittgen (2007) for data preparation and have developed IT-support to generate high-level analytics of collaboration processes. More specifically, they analyze the collaboration along the flow of modeling, i.e., related to the sequence of the performed actions, and along their distribution among the involved actors. This allows to study actor's behavior in the group, creating a comprehensive picture of the collaboration process.

Taking a similar perspective, Hoppenbrouwers et al. (2005) argue for considering the process of collaborative conceptual modeling to be a dialogue among the involved actors. In contrast to the approaches described above, the object of investigation here is the whole social setting the modeling session is conducted in. Hoppenbrouwers & Rouwette (2012) adopt this approach and use the concept of "focused conceptualizations" (FoCons (Hoppenbrouwers & Wilmont 2010)) to split the modeling process into its different conversational topics. FoCons are analyzed regarding different aspects of the modeling process (e.g. required input, desired outcome, participants, guidance measures, type of abstraction activity, etc.).

Forster et al. (2013) focus on observing the process of model creation. Observations are derived automatically from logs that are created by computer-supported modeling environments. The object of investigation consequently are observable changes in the model created by the actors. They propose different visualizations to indicate activities of modelers. This includes heat-map overlays of the model to indicate areas that have been subject to more frequent changes or timeline-based modeler activity diagrams, which can be used to identify turn-taking in modeling activities. Pinggera et al. (2012) propose to use modeling phase diagrams to visualize the evolution of the model over time, identifying the sequence of different types of modeling activities. In further research, Pinggera et al. (2013) examined, how to use eye movement analysis to investigate the activities of individuals involved in a collaborative modeling process. Recker et al. (2013) propose an approach that focusses on cognition of the actors involved in collaborative modeling and collect data using an ex-post questionnaire (i.e. do not observe the modeling process directly).

In a third strain of research, efforts have been made to describe evaluation approaches on a meta level to make them adaptable to different foci of evaluation. Ssebuggwawo et al. (2013) propose to use the analytical hierarchical process (Saaty 1990) to examine collaborative modeling processes. By implementing their framework, modeling process evaluation can be conducted from different perspectives and using different objects of investigation, such as the modeling language used, the modeling procedure, the produced model and the medium used for modeling (i.e., tool support). This approach thus can be considered an operationalization of the framework proposed by Gemino & Wand (2004). It, however, does not offer new approaches to examining the operative procedure of collaborative modeling itself but refers to methods that have already been discussed above.

5.2.2 Review of objects of investigation

In an attempt to systematically review the current state-of-the-art, the approaches described above, which directly observe the process of collaborative modeling, have been examined regarding which object(s) of investigation they use to derive claims about aspects of an observed collaborative modeling session (summarized in Figure 5.1). All reviewed approaches derive their claims based on a single object of investigation. They differ in where they draw their data from – Rittgen (2007) and Seeber et al. (2012) use the utterances of the actors as their main source of information, Forster et al. (2013) and Pinggera et al. (2012) draw their information from the sequence of model changes, and Hoppenbrouwers & Rouwette (2012) observe the social setting of the modeling session and the interaction among the actors as a whole. These different objects of investigation to the best knowledge of the author so far have not yet explicitly been used in combination to examine collaborative modeling sessions. This leads to the question, whether a combination could provide added value and allow to derive claims that go beyond the currently proposed aspects. We will get back to this question at the end of Section 5.5.

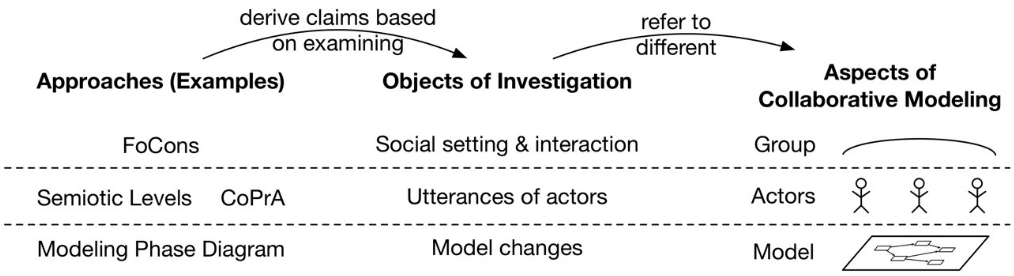

Figure 5.1: Different objects of investigation used in reviewed related work

5.2.3 Review of addressed analytical dimensions

Using the analytical dimensions of an approach as a means for structuring related work furthermore reveals that not all potentially relevant aspects are equally covered by existing approaches. The structure depicted in Figure 5.2 has been inductively derived from the reviewed approaches. It was validated and augmented with the framework proposed by Krogstie et al. (2006). Related work analyses collaborative modeling processes along the following dimensions:

- The manipulation of the *model* by the *actors* is analyzed on the syntactic level of Rittgen (2007)
- The interaction among the *actors* to come to decisions as a *group* is analyzed on the pragmatic and social level of Rittgen (2007) and also is addressed in CoPrA (Seeber et al. 2012) in more detail. FoCons (Hoppenbrouwers & Rouwette 2012) take a different perspective on this dimension and analyze the roles of the involved actors.
- The process of building a *model* as a *group* is examined in Modeling Phase Diagrams (Pinggera et al. 2012).
- The way of representing statements about the *topic* to be modeled (i.e. domain knowledge) in the *model* is addressed on the semantic level of Rittgen (2007).
- The development of a common understanding within the *group* about the *topic* of modeling is only explicitly addressed in FoCons (Hoppenbrouwers & Rouwette 2012) by describing guidance measures, observed abstraction activities and used information resources.

The cornerstones of the structure (*model, actors, group, topic*) remain stable throughout all reviewed approaches. This is in line with the main elements of the framework for assessing process model quality presented by Krogstie et al. (2006), which puts particular focus how *actors* could use *modeling* to extend their knowledge about the target domain (i.e. the *topic*) and how *models* could enable them to act within the domain.

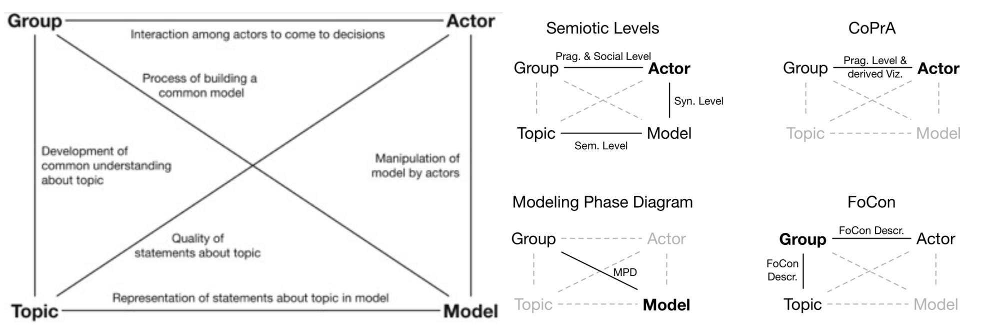

Figure 5.2: Analytical dimensions for collaborative modelling sessions (left), coverage of analytical dimensions in reviewed related work (right)

5.2.4 Gap Analysis

When reviewing the links between the cornerstones (cf. Figure 5.2, right), it is obvious that the link between *actor* and *topic* currently is not addressed in any of the available approaches. Krogstie et al. (2006), however, indicate that this link would be high relevance when examining modeling processes, as it could be used to analyze the quality of statements actors make about the topic of modeling and how it changes over time, pointing at potential knowledge transfer about the topic among the different actors. This claim also is coherent with Gemino & Wand (2003), who argue for considering modeling techniques as facilitators of learning processes and consequently evaluating them regarding their effects on actors' understanding about the topic.

An analytical approach filling this gap thus has to explicitly consider the quality of the statements articulated by actors about the topic of modeling in a collaborative setting. To the best knowledge of the author, no existing approach in collaborative modeling addresses this requirement. Search has thus been extended to domains that examine social processes in collaborative work on a common topic. An approach potentially filling the identified gap has been proposed by Weinberger & F. Fischer (2006). Their methodology has been developed to assess argumentative construction of knowledge in collaborative learning settings. Its analytical dimensions can be mapped to the structure proposed above and explicitly address all links between *actor*, *group*, and *topic*. The next section describes how the links are instantiated in the proposed analytical dimensions and how the approach has been adapted to be suitable to analyze collaborative conceptual modeling processes.

5.3 Evaluating collaborative modeling from an articulation and alignment perspective

The review of related work has shown a lack of support for evaluating collaborative modeling activities from an articulation and alignment perspective. Articulation and alignment here are to be understood as individual and collaborative activities related to externalizing actors' views on a given topic (Strauss 1993) and aligning them to avoid problems during operative collaboration (Vennix et al. 1996). As such, articulation has also been recognized as an important component during the process of conceptual modeling (Krogstie et al. 2006).

One approach that explicitly addresses the quality of articulation and alignment activities in the evaluation of collaborative problem solving processes is proposed by Weinberger & F. Fischer (2006). It has been successfully deployed and validated in collaborative learning settings and allows to examine how articulate their views about a given topic and how they interact as a group to develop a common understanding. The dimensions they propose for the classification of the actors' articulation and alignment activities are derived from literature, which describes observable phenomena in the process of the collaborative construction of knowledge. Due to original scope of the approach, it does not explicitly consider modeling activities. Still, the proposed dimensions are applicable, as modeling can be considered a sub-class of generic "problem solving" activities (Lesh & Harel 2003). In the following, we review the original analytical dimensions and describe their adaptation for examining collaborative conceptual modeling sessions.

5.3.1 Object of Investigation

The object of investigation of Weinberger & F. Fischer (2006) are textual statements made by actors in a collaborative (online) environment. The content of the statements is reviewed and classified in the different dimensions described below. In collaborative modeling, the units of analysis are not necessarily bound to verbally articulated statements but can also be constituted by modeling activities. In the following, we thus discuss which object(s) of investigation can be used to appropriately collect data for the application of the approach.

As noted above, some modeling evaluation approaches (e.g. (Pinggera et al. 2012)) use data generated by IT-supported modeling environments to identify their units of analysis. The object of investigation are the models themselves, actors – if at all – are only indirectly considered in the analysis. Approaches focusing on actors' behaviors (e.g. (Rittgen 2007; Seeber et al. 2012)) often use transcriptions of utterances of actors, partially in combination with model changes as their objects of investigation. The transcriptions are either drawn from technologically mediated communication tools (e.g. chats) or retrieved from video recordings of co-located modeling sessions. Approaches targeting to analytically describe the overall social setting (e.g. (Hoppenbrouwers & Rouwette 2012)) use similar approaches. Ssebuggwawo (2012) gives an overview about potential approaches to collect data about collaborative modeling sessions and how to prepare them for analysis.

For the present work, the main objects of investigation are the statements made about the topic by the actors during collaborative modeling. In order for the approach of Weinberger & F. Fischer (2006) to be applicable, the units of analysis must be segmented to form epistemologically self-contained statements, i.e., refer to a single aspect of the topic. In addition, in the context of collaborative modeling, acts of modeling, which not necessarily are accompanied by verbally articulated statements, also need to constitute distinct units of analysis. Consequently, units of analysis are separated if one of the following events occur:

- persons finishing the articulation of a self-contained statement (i.e. a statement that can be interpreted without considering other utterances). Finishing can be identified by turn-taking (i.e. another person taking over) or semantic distinction (i.e. continuing with a statement referring to a different topic). Utterances made by several persons at the same time on the same topic, where no clear semantic distinction can be made, do not constitute distinct units of analysis.
- persons finishing a manipulation of the model. A manipulation is finished as soon as a person continues with the manipulation of a different area of the model or turn-taking occurs. Simultaneous manipulations do not constitute distinct units of analysis.

The identified units of analysis are classified along different analytical dimensions as described in the following.

5.3.2 Analytical Dimensions

The interaction of the involved actors during collaborative problem solving is assessed in the following dimensions (Weinberger & F. Fischer 2006):

- Actor Participation
- Epistemic nature of statements
- Argumentative quality of claims
- Social Modes of Co-construction

The classification categories specified in these dimensions are interpreted with respect to their application in collaborative modeling settings in the following. In addition, the present chapter extends the methodology to also assess manipulations of the model. This allow to put the social interactions among the actors in the context of their modeling activities.

The *participation dimension* refers to the amount of contributions made by the actor. This includes two aspects: the quantity of participation for each actor and the heterogeneity of participation, i.e., the amount of turn taking happening during the modeling process. Participation is not limited to utterances (verbal or written, depending on the source of the analyzed material) but also includes manipulations of the model. During analysis, the actually involved persons are identified for each unit of analysis. Each actor is assigned a unique identifier that allows tracking of the amount participation and involvement in turn-taking for each individual.

The *epistemic dimension* refers to the quality of contributions made in one unit of analysis. Each unit of analysis is classified in a single category. The following scheme is used for classification: An initial distinction is made between on- and off-task statements. Off-task statements comprise all statements which are content-wise not related to the topic of modeling. On-task statements are distinguished based on their content. Following Weinberger & F. Fischer (2006), statements can refer to: (a) the problem space. Statements in this category refer to the concrete case that is currently articulated or discussed; (b) the conceptual space. Statements in this category refer to generalizations of a concrete case and cover theoretical considerations about the generic aspects of the current issue; (c) the relationships between problem and conceptual space and their adequacy. Statements in this category link case-specific and generic statements. Judging whether the uttered relationship is adequate or inadequate requires a coder to have domain-specific knowledge. As this knowledge not necessarily is available, considering this distinction is optional but allows to conduct a more informed analysis of the modeling process regarding processes of developing an understanding of the topic of modeling; and (d) the relationships between the problem space and prior knowledge.

Statements made in this category link case-specific statements to prior knowledge of an actor.

The *argumentative dimension* focusses on contributions to problem inquiry and resolution observable in the units of analysis. In a first analytical step, claims made by the actors are identified. Each unit of analysis either constitutes a non-argumentative move or an argumentative claim. Claims can be qualified or grounded. Actors explicitly limit the validity of qualified claims validity through describing the context in which the claim is assumed to be valid. Grounded claims are argumentatively backed by the actors through further justifications, which explain why they are assumed to be valid. Claims can also have both qualities, or exhibit neither of them. The latter cases are considered "simple claims". In a second analytical step, according to Weinberger & F. Fischer (2006), the claims should be analyzed regarding their role in a sequence of arguments. Claims can act as arguments, counterarguments, or integrative statements. In collaborative modeling sessions, the identification of such chains can be challenging due to the dynamic nature of discourse. It thus might not always be feasible to perform this second coding step.

The final dimension of the original approach addresses the *social modes of co-construction*. It classifies the observed discourse with respect to how the actors as a group create align their understanding about the topic and formulate arguments together. Units of analysis that contain content referring to the topic of modeling (as identified in the epistemic dimension) here are distinguished into externalization, elicitation, and consensus-building activities. Externalization refers to units during which actors contributes its own view on the current topic of discourse. Elicitation activities refer to actors questioning others or provoking reactions. Consensus-building can again take different forms. Their identification is described in detail by Weinberger & F. Fischer (2006) and summarized in the following: In "quick consensus building", contributions of one actor are accepted by the group implicitly or explicitly without any modification and any "indication that the peer perspective has been taken over" (Weinberger & F. Fischer 2006) by the other learners. Quick consensus-building does not give any indication, if knowledge alignment has taken place. "Integration-oriented consensus building" means that actors take over positions of other actors and extend and validate these positions with own input. A unit rated in this category must show statements that "significantly differ(s) from a juxtaposition of perspectives, but indicates a further development of the analysis" (Weinberger & F. Fischer 2006) by an actor. "Conflict-oriented consensus building" is characterized by actors, who not accept contributions of others as they are, but challenge. They require adaptation of the articulated positions in order to achieve a common understanding. Units that should be rated in this category are indicated by "rejection, exclusion or negative evaluation of peer contributions" (Weinberger & F. Fischer 2006), either explicitly or implicitly by ignorance or replacement of a contribution.

The *modeling dimension* describes model manipulations performed by the actors. These manipulations can take different forms, which are informed by those described by Rittgen (2007) for the syntactic level of modeling analysis: (a) adding elements to the model, (b) changing the layout of the model (i.e. rearranging elements), (d) merging duplicate modeling elements or removing them (which is common, when actors contribute individually prepared model elements to a shared model). Further model manipulations can be added to the available analytical categories in this dimension, if they are considered relevant for the applied modeling methodology at hand (e.g., an analysis of the generation of BPMN models might benefit from an identification of model manipulations during which modifiers are added to already existing model elements).

5.3.3 Summary

Figure 5.3 shows the analytical dimensions of the proposed approach embedded in the structure used to review related work. The main objects of investigation are the statements on the topic of modeling made by the actors. Due to the extension of the original approach to also consider modeling activities, the actors have to be included as secondary objects of investigation mainly with respect to their manipulations of the conceptual model. The main contribution of the proposed approach is the explicit analysis of the quality of statements made by the actors about the topic (link between *actor* and *topic*), which is covered by the epistemic dimension. Statements on the topic are classified there regarding their point of reference. The same aspect is addressed in the first step of the analysis in the argumentative dimension, in which claims about the topic are classified regarding how they are embedded in the overall topic. In addition, the co-construction dimension enables a more detailed, fine-grain analysis of how the group works on the development of a common understanding about the topic than is enabled by using FoCons. The second part of the argumentative dimension as well as the participation dimension on the link between *group* and *actor* enables an analysis similar to that proposed in CoPrA. The modeling dimension is derived from the approach of Rittgen (2007) and consequently leads to similar results.

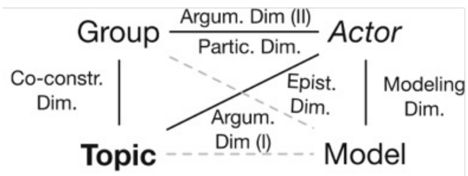

Figure 5.3: Coverage of analytical dimensions in the presented approach

The contribution of the approach introduced in this chapter has now been outlined on a conceptual level. Its practical added value is demonstrated in the next section by conducting a comparative review of the present approach with those presented in related work based on a real-world case.

5.4 Comparative review of evaluation approaches

The aim of the comparative review is to contrast the evaluation results of the present methodology with those achievable with related approaches. It demonstrates that the analytical dimensions are complementary to those already proposed in related work and shows the potential value that can be generated by combining those dimensions.

Methodologically, a real world collaborative modeling session is used as a sample case. This case has been selected based on the exposed heterogeneity of interaction among the actors and the different model manipulation activities that are contained. The case has been used consistently as the subject of analysis for the different evaluation approaches. This allows to compare the results and discuss the different qualities of the generated data. For reasons of diversity, one approach of each of the strains of research identified in the related work section has been selected for the following comparison. We start with the coding approach proposed by Rittgen (2007), where coding is structured along different semiotic levels. The next section describes the application of the CoPrA approach (Seeber et al. 2012). As a representative of model-centric evaluation approaches, the modeling phase diagram (Pinggera et al. 2012) is presented in the next section. We continue with describing the results of the methodology introduced here. Finally, we analyze the sample case along its conversational structure as proposed by Hoppenbrouwers & Rouwette (2012). In the subsequent section, we discuss the results of these codings regarding conceptual overlaps and potentially complementary dimensions. We finally give an account on the implications of adopting an articulation and alignment perspective when evaluating collaborative modeling sessions.

5.4.1 Sample Case

The sample case used for comparing the different evaluation approaches has been selected from a series of modeling workshops aiming at the facilitation of creating a shared understanding about a work process for inexperienced modelers. The modeling methodology is inherently cooperative and relies on a combination of articulation, elicitation, and negotiation to ultimately reach common ground on the way the work process should be implemented. It is described in detail in (Oppl 2016d). The case was conducted in a school for vocational training in healthcare in Germany and dealt with the process of organizing one's practical placement to gain professional experiences. The modeling session reviewed here is an excerpt of the whole workshop and lasted 31 minutes and 9 seconds. It was preceded by an introduction to the modeling methodology and a phase of individual reflection on each actor's role within this process. It was followed by a plenary discussion on the implications of the generated models. During the collaborative modeling session, a total of 9 actors actively contributed to the modeling process. 8 of them were female, 1 of them was male. Their age ranged between 18 and 42. None of them had prior experiences in any form of conceptual modeling. The process was facilitated by a teacher of the vocational training school, who had participated in a facilitation training offered by the developers of the modeling methodology.

The modeling result of the evaluated modeling session is shown in Figure 5.4 to provide context to the following discussions. Modeling follows an interaction-based paradigm of describing collaborative work processes. Blue elements represent the involved process participants, red elements represent the activities of these participants (with causality indicated by the vertical order of the elements), and yellow elements represent acts of interaction or communication between the connected participant lanes. The modeling language is described in more detail by Oppl & Alexopoulou (2016).

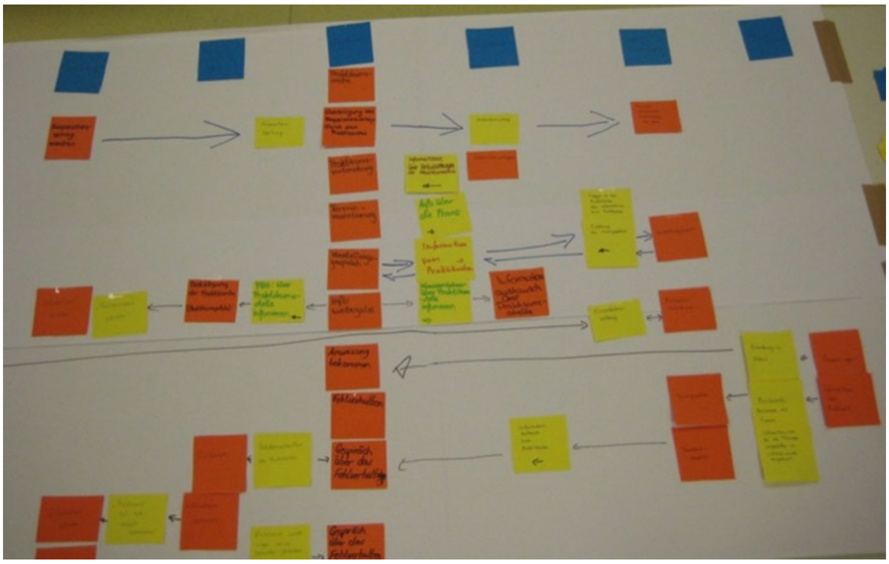

Figure 5.4: Modeling result of sample case

5.4.2 Identification of units of analysis

In order to analyze the modeling process, the units of analysis need to be identified as described above. The modeling session was recorded on video in order to enable the creation of a concurrent verbal protocol (Trickett & Trafton 2009). Instead of using think-aloud to further enrich collected data (as proposed by Trickett & Trafton (2009) and also adopted by Rittgen (2007)), the sample case was recorded without intervention, only collecting statements uttered in the context of collaborative modeling, but including the modeling activities of the actors. Segmentation was performed by two independent raters and consolidated by the coordinator of the study. Overall, 117 distinct units of analysis were identified. Evaluation was conducted independently by two raters to avoid rater's bias following the procedure proposed by Trickett & Trafton (2009). Raters have been trained using a five-minute video sequence of the same modeling method.

They were provided with a code-book based on the descriptions of the evaluation methods. The inter-rater reliability was assessed using Cohen's Kappa. The test coding conducted after the first training led to a value for Cohen’s Kappa of 0.506. After a revision and clarification of the code-book and another training session, another sample video was coded, reaching a value of 0.932 for Cohen's Kappa.

In the following, the different evaluation approaches are presented in a diagrammatical format that allows to compare their results (cf. Figures 5.5 and 5.10). The coding results for each result are presented in a time-proportionally scaled visualization of the units of analysis on the x-axis. Coding categories are stacked on the y-axis clustered along the addressed dimensions. In addition, derived visualizations of the data are provided, if they are described in the source articles. Based on these visualizations, we discuss potential conclusions about the sample case that can be drawn from the coding results. In addition, we provide a description of the limitations encountered during coding.

5.4.3 Coding structured along semiotic levels

Coding was carried out based on the method description provided by Rittgen (2007).

5.4.3.1 Analytic dimensions

Collaborative modeling session are analyzed along four different dimensions. The *syntactic level* refers to manipulations of the model, in particular adding, removing, or altering nodes or edges. The *semantic level* describes statements referring to the content of model, i.e. statements that are used to describe the subject that should be depicted in the model. The *pragmatic level* describes the interaction of the modelers during the process of model manipulation. This includes proposals and questions as well as negotiation-related activities such as supporting statements or objecting them. The *social level* refers to observations on the behavior of the actors when making decisions about proposals. While decision making can take different forms, Rittgen (2007) explicitly mentions rules of majority and rules of seniority as prominent examples for this dimension.

5.4.3.2 Coding Result

Applying these dimensions to the sample case leads to the results visualized in Figure 5.5 (left). Coding on syntactic and semantic level has been affected by the modeling methodology used in the sample case. The paper-based modeling methodology does not separate the process of adding an element to the model from labeling it. The activity type “labeling of nodes and edges” thus is only used, when labels of already exiting nodes or connections are changed. The limited expressiveness of the modeling language used in the sample case renders some of the categories on semantic level redundant. As the language is tailored to describing case-based models, forks or branches cannot be observed.

5.4.3.3 Observations regarding the sample case

The visualization in Figure 5.5 (left) makes visible four prominent phases of the modeling process. Until approximately minute 5, low amounts of modeling activities are observable. The focus of interaction clearly is put on making proposals about the content of the model. This is followed by a second phase of intense and dynamic interaction that lasts from minute 5 to minute 16. This phase is characterized by sequences of asking questions and providing clarifications about the modeling subject, with frequent additions of nodes and edges to the model. From minute 16 to 23, hardly any manipulations of the model can be observed. This is accompanied by a less dynamic sequence of questioning the content of the model in the pragmatic dimension. Starting from minute 23 until the end of the observed session, the coding shows changes being made to existing elements in the model. These changes are accompanied by a large amount of clarifications (visible in the pragmatic dimension), which are accepted by the group without formally entering a negotiation process (visible in the social dimension).

5.4.3.4 Limitations on coding and interpretation

Analysis of the semantic level requires to have a detailed view on both, the content of the model and how it is changes as well as the interaction of the modelers. Co-located modeling sessions without technical support, such as the sample case, often suffer from restrictions on data collection (e.g., the opportunity to use multiple cameras). Analysis of this dimension thus can hard to be carried out unambiguously.

The syntactic level does not account for changes to the model layout. While layout changes in general do not change the syntax of a model, the sample case shows that the spatial arrangement of modeling elements is used to reflect pending proposals that still need to be agreed upon. Considering layout changes thus could add data relevant for overall analysis of the modeling process.

The method also does not allow to code off-topic interventions such as explanations about the modeling methodology provided by a facilitator. As such interventions can have significant impact on the modeling and negotiation process, their identification could be of interest for the analysis.

The method does not allow to describe simultaneous interaction of multiple actors. The co-located modeling setup, however, facilitates such behavior, which cannot be appropriately represented in the coding scheme.

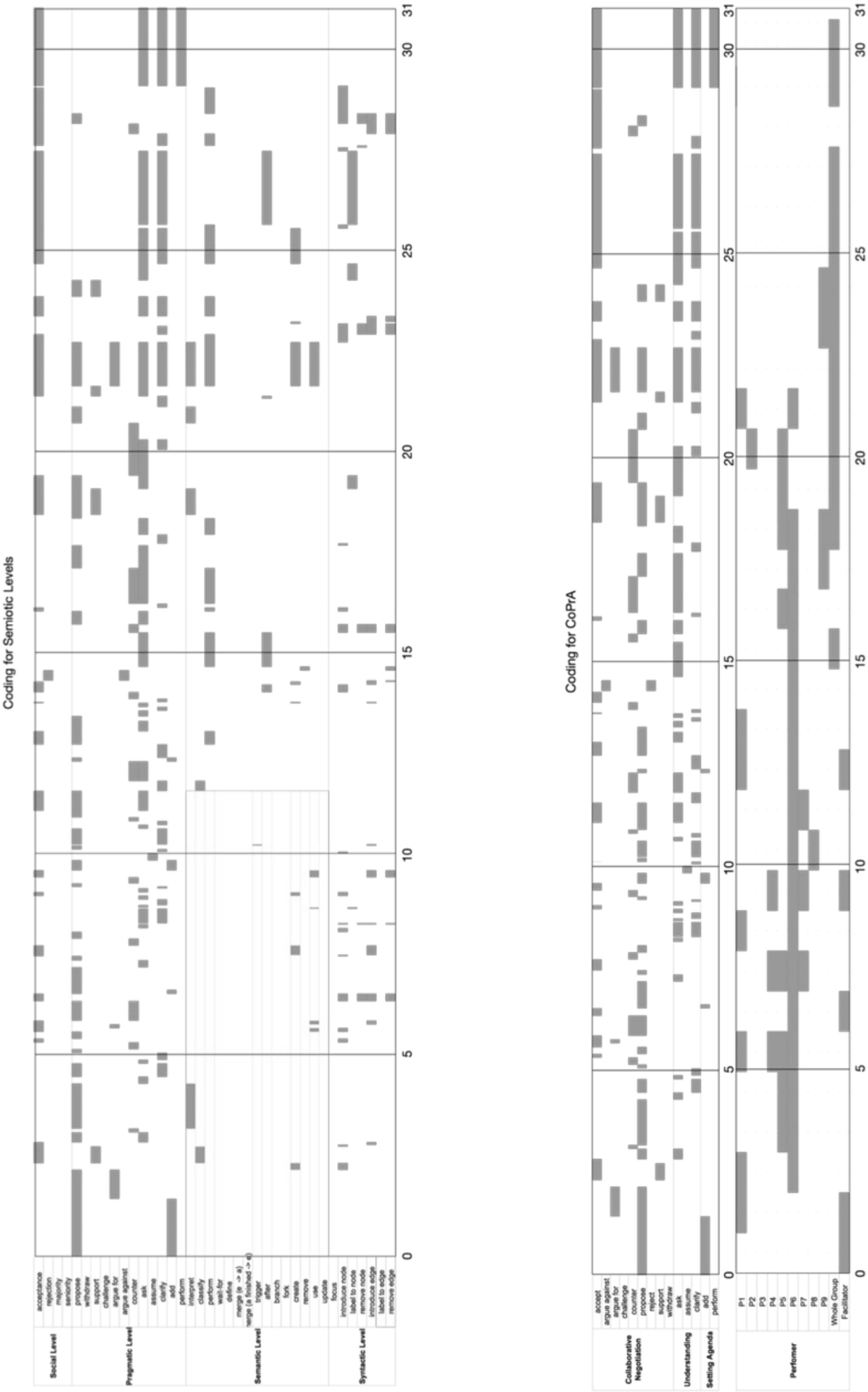

Figure 5.5: Coding results for semiotic levels (left) and CoPrA (right)

5.4.4 CoPrA

CoPrA (Seeber et al. 2012), in its original implementation, is implemented in a tool, which supports coding of pre-segmented modeling sessions and allows to carry out higher level analytics of the modeling process automatically (e.g. in terms of time distributions for different modeling activities, etc.). In order to allow for consistent comparison, the tool has not been used here.

5.4.4.1 Analytic dimensions

CoPrA does not explicitly focus on collaborative modeling processes, but aims at analyzing collaboration processes in general. CoPrA adopts the work of Rittgen (2007) for analysis of collaboration. CoPrA clusters the categories of the pragmatic level in (a) those aiming at setting the agenda of the collaborative process, (b) those aiming at understanding the topic at hand, and (c) those aiming at collaborative negotiation processes. In contrast to Rittgen (2007), CoPrA analyzes the individual contributions of the actors during the collaboration process. Participation of an individual actor is a binary category for each unit of analysis and is not categorized any further.

Higher level analytics is generated based on this coding. Analytics include distribution of action types (based on the categories specified by Rittgen (2007)) and distribution of contributions by actor. Both distributions are proposed to be visualized as pie charts, showing relative amounts, and as time-line based diagrams, showing the absolute amount of observed occurrences in a given time-interval.

5.4.4.2 Coding Result

Applying CoPrA to the sample case leads to the observations visualized in Figure 5.5 (right). The upper coding table resembles the pragmatic dimension of the coding presented for the methodology of Rittgen (2007). The lower coding table indicates participation for each of the 9 actors. As an addition to the original methodology, participation of the facilitator has been added as well as participation of the whole group. The latter has been used when the dynamics of interaction did not allow to identify single active actor.

Based on this coding, higher level analytics were generated. Figure 5.6 shows the distribution of activity types overall and separated by the categories identified above as pie charts.

Figure 5.6: Distribution of activity types in sample case

Figure 5.7 gives an overview about the relative amount of participation for all actors as a pie chart.

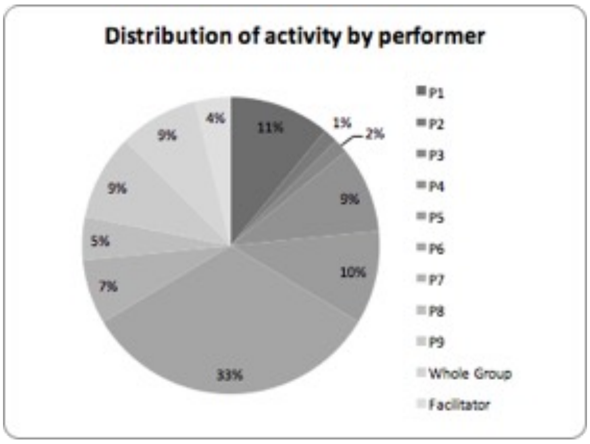

Figure 5.7: Relative amount of participation per actor in sample case

Figure 5.8 shows examples for the timeline-based analysis of the distribution of action types (above) and amount of participation (below). The interval chosen for visualization has been 1 minute. The stacked column chart on the left is a form of visualization chosen in the present chapter, whereas the line chart resembles the originally proposed form of visualization. These different forms have been chosen to discuss differences in potential observations below.

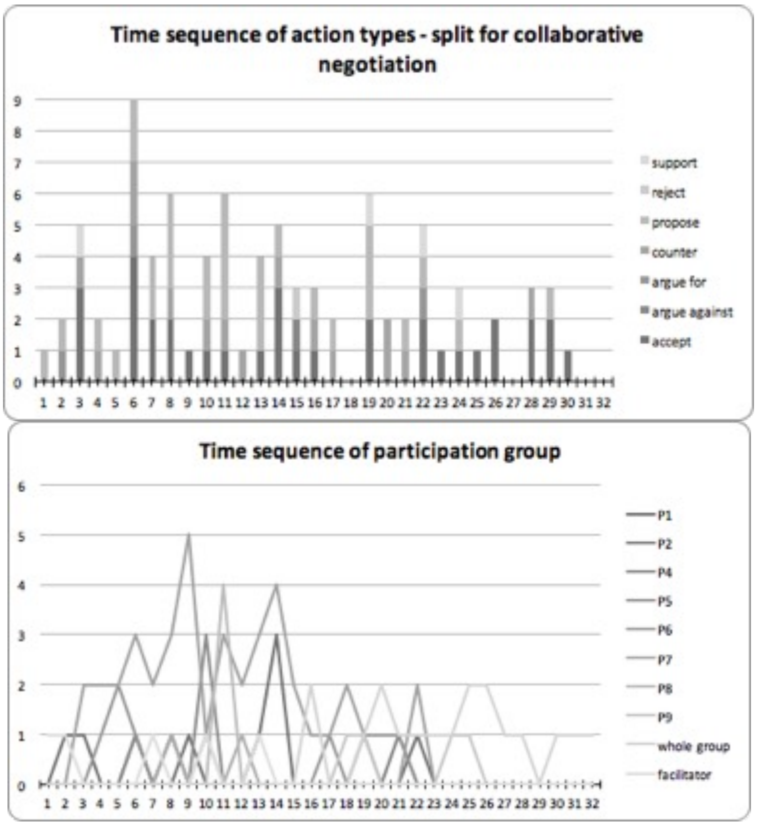

Figure 5.8: timeline-based visualization of action types (above) and participation (below)

5.4.4.3 Observations regarding the sample case

As the fundamental coding scheme closely resembles the coding following the pragmatic level of Rittgen's (2007) scheme, the findings described above also apply to the methodology discussed in this section. CoPrA is not tailored to the analysis of collaborative modeling processes in particular, and thus lacks analytical dimensions reflecting model manipulation.

The coding of individual actors' contributions gives a more comprehensive picture of the interactions among the actors. Specifically, it shows a very heterogeneous amount of participation of the involved actors. P6 is responsible for one-third of the activities observed in the modeling process, whereas P2 and P3 only have contributed to less than 2% of the observed activities. 9% of the activities could not be assigned to specific persons and are considered activities of the whole group. When reviewing the timeline-based visualization of participation, the phase of dynamic interaction between minutes 5 and 15 identified in the former section are clearly visible here, too. They show that most of these activities can be attributed to P6 interacting with P4 and P8. The final phase of modeling shows a large amount of interaction in the whole group that could not be assigned to a specific person.

The visualization of the distribution of activity types show that 60% of the observed activities were dedicated to negotiation activities and 37% were concerned with activities dedicated to creating mutual understanding about the topic. Only 26% of the negotiation activities were concerned with actual discussion activities, whereas 36% were proposals, which often were accepted without further discussion (38%). The timeline-based visualization shows that the largest share of discussion-oriented negotiation activities is again located in the timespan between minutes 6 and 15.

5.4.4.4 Limitations on coding and interpretation

CoPrA focusses on analyzing interaction in collaboration processes and does not consider model manipulation activities. Data capturing consequently can focus on the interaction of the actors. The data needs to allow the identification of the contributor of each statement. The challenge of handling dynamic interaction situations with inseparable individual contributions has been addressed by explicitly introducing a coding category for the whole group.

The higher-level analytics proposed in CoPrA can be derived solely from the coding results as described above and do not require additional metadata. More complex analytics, such as the HeuristicNet proposed by Seeber et al. (2012) to visualize the probability of activity sequences, rely on advanced data mining techniques and thus require dedicated tool support, as available in the CoPrA toolset.

5.4.5 Modeling Phase Diagrams

Pinggera et al. (2012) introduce an analytical method for the process of process modeling. This process not necessarily is collaborative. The method explicitly also can be applied for individually created models. While the authors demonstrate the applicability of their approach for the area of process modeling, it can be generalized for analyzing conceptual modeling processes in general. They consider the process of modeling to be an iterative process which exposes different phases of activities.

5.4.5.1 Analytic dimensions

Pinggera et al. (2012) propose to split the modeling process in distinct phases based on the observable types of activities. They identify three fundamental types of activities: During *comprehension*, the group tries to understand the topic to be modeled and/or the content already represented in the model. During *modeling*, this understanding is used to manipulate the model, i.e. adding or removing nodes and edges or otherwise changing the structure of the model. *Reconciliation* phases are identified, when the model is reorganized to enhance its understandability. This includes renaming of nodes and edges as well as altering the layout of the model.

These phases are identified by interpreting the observable modifications of the model. Similarly to the syntactic dimension proposed by Rittgen (2007), the authors propose to identify each act of model manipulation, distinguishing between structural changes and reorganization of an existing model. Sequences of structural model changes are classified as *modeling* phases, whereas sequences of model reorganization activities are classified as *reconciliations* phases. Sequences with no observable modeling activities are classified as *comprehension* phases.

The classification results are visualized using a timeline-based diagram. The number of model elements is displayed over time, showing the evolution of the model size during the process of modeling. Each line segment (i.e., each phase identified above) is displayed with a different stroke type to enable the distinction of the phases.

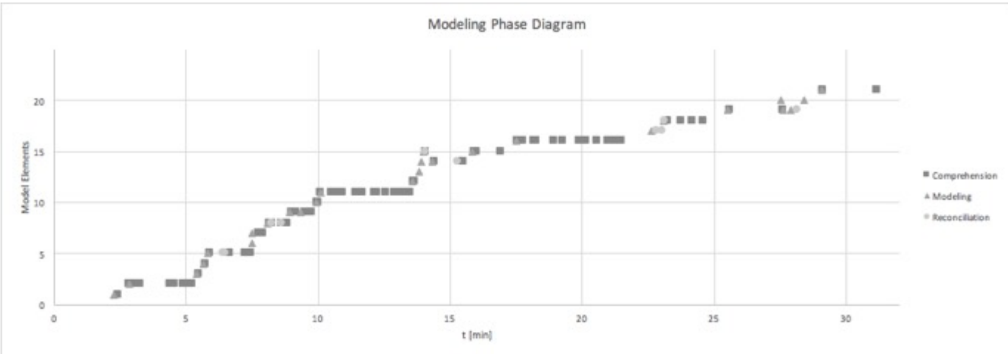

Figure 5.9: Modeling Phase Diagram

5.4.5.2 Coding Result

Figure 5.10 (left) shows the coding performed according to the criteria identified above. Modeler interactions have been identified based on the observable model manipulations. The modeling phase diagram shown in Figure 5.9 has been derived from this coding. In contrast to the originally proposed form of visualization, the diagram has been augmented with information on turn-taking, which is relevant for collaborative modeling processes. Visualization is based on the units of analysis identified in the source data. The start of each segment has been represented with a data point in the diagram, where its shape indicates the type of phase it belongs to. Regions with a high density of dots consequently indicate a large amount of turn taking, whereas gaps in the diagram indicate longer lasting activities of a single contributor.

5.4.5.3 Observations regarding the sample case

Both visualizations (Figure 5.9 and Figure 5.10 left) indicate that the largest share of modeling time is dedicated to comprehension activities, which are not directly reflected in the model. Model manipulations occur in batches, which are interrupted by longer phases of comprehension. The most dynamic phase of the modeling process can be found between minutes 5 and 10, which is indicated by a quickly rising modeling size and a heterogeneous sequence of rather short modeling, reconciliation and comprehension activities. Reductions in model size only occur twice and in both cases can be accounted to the removal of edges in the model (as identifiable in the coding table in Figure 5.10 left). Other than that, the model is constantly increasing in size. The later phases of modeling are characterized by longer comprehension phases without any observable turn taking.

5.4.5.4 Limitations on coding and interpretation

In contrast to the former methods, the application of this method only requires the availability of data about model manipulations. As the method does not take into account whether modeling is an individual or a collaborative act, data about the individual actors are not required. The algorithm specified by Pinggera et al. (2012) allows to identify phases solely based on model manipulations.

The chosen object of investigation also appears to lead to a major limitation of the approach, especially when applied in collaborative settings. No observable modeling activity not necessarily means that comprehension activities take place. Simple breaks or off-topic interactions between actors cannot be identified as such, when solely relying on data generated from observed model manipulations.

5.4.6 Coding structured along articulation and alignment of knowledge

The different dimensions of the method introduced here are informed by concepts to describe discourse happening in the context of knowledge articulation and alignment, in particular the concept of creating common ground among a group of actors (Clark & Brennan 1991).

5.4.6.1 Analytic dimensions

The analytic dimensions of the framework have already been described in Section 5.3. Summarizing, collaborative modeling sessions are analyzed regarding the amount of *participation* by the involved individuals, the *epistemic* quality of the statements contributed by the actors, the *argumentative* quality of claims uttered in the course of collaboration, and the observable *social modes of co-construction*. The original framework of Weinberger & F. Fischer (2006) is augmented with an additional dimensions reflecting *model manipulations*.

5.4.6.2 Coding Result

Figure 5.10 (right) shows the coding result for the sample case based on the dimensions introduced above. The participation dimension has been augmented with information on how many actors were active in units of analysis showing simultaneous activities.

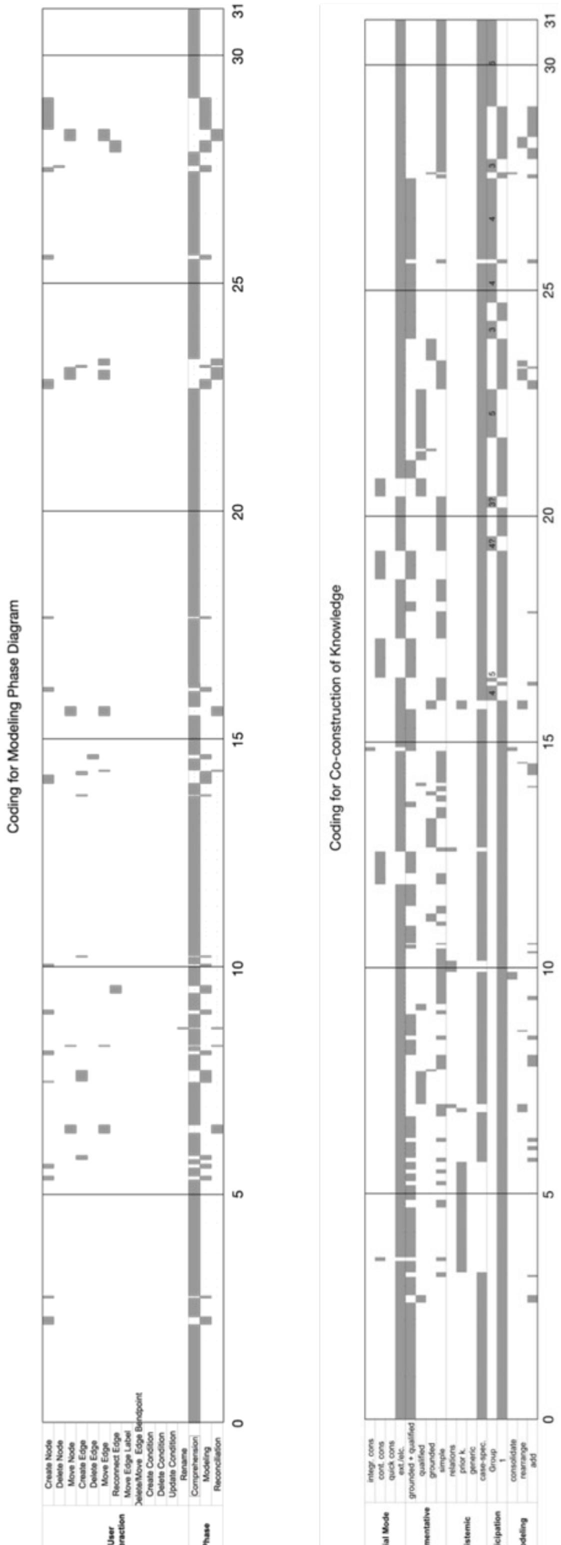

Figure 5.10: Coding Result for Modeling Phase Diagram (left) and Co-construction of knowledge (right)

5.4.6.3 Observations regarding the sample case

Reviewing the patterns in Figure 5.10 (right) reveals 4 phases in the modeling process: Until minute 6, hardly any modeling activities took place. This phase is largely dedicated to articulation of individual views on the work process to be modeled. At minute 3, a brief sequence of controversial statements (cf. social mode) led to a switch from discussing the case at hand to referring to prior knowledge (cf. epistemic dimension). The switch back to discussing the actual work process at minute 6 also marks the end of the first phase. It is followed by a phase of intense modeling activities, which lasts until minute 11. Here, individuals contribute their views without being fundamentally questioned. From minute 12 to 21, a phase characterized by controversial consensus building activities can be recognized (cf. social mode). The participation dimension indicates dynamic interactions, as group-level interactions start to occur more often. Starting from minute 22 until the end of the modeling session, a large amount of group-level interactions is observable (cf. participation dimension), which is accompanied by frequent modeling activities, in particular layout changes (cf. modeling dimension). Claims are better grounded than in the preceding phases, indicating a more careful line of argumentation for the final changes to the model (cf. argumentative dimension).

Overall, the "social modes of co-construction" show a large amount of the modeling time being dedicated to elicitation and externalization activities. Explicit consensus building activities could hardly be observed. The epistemic dimension shows that most of the discussions referred to the concrete work case being discussed. No attempts to generalize the findings to a more abstract level were made. This, however, is in line with the aims of the modeling technique, which explicitly facilitates the construction of case-based models.

5.4.6.4 Limitations on coding and interpretation

As the proposed evaluation methodology requires to observe statements of the actors regarding the topic of modeling and model manipulations at the same time, it faces similar challenges as the coding based on semiotic levels as proposed by Rittgen (2007). Still, as it does not describe activities related to model content in detail, data collection not necessarily needs to include details on the created model.

5.4.7 FoCon-based analysis

For FoCon-based analysis (Hoppenbrouwers & Rouwette 2012), source data needs to be split along discernible topics of discourse in a modeling process. Each FoCon is described with respect to different aspects of both, model building and interaction, which are described in the following.

5.4.7.1 Analytic dimensions

The identification of FoCons is based on changing topics of discourse. Hoppenbrouwers & Wilmont (2010) state that the granularity of segmentation of FoCons is dependent on the level of abstraction one takes when analyzing a modeling session. A single FoCon could be used to describe a modeling session as a whole on an abstract level, whereas FoCons also can be used to decompose a modeling session into different segments with a more constrained focus of discourse.

Each FoCon is described using the following information categories (Hoppenbrouwers & Wilmont 2010): *input* ("what may or must go in") describes required information and sources thereof; *outcome* ("what should come out") describes the desired syntactic, semantic and pragmatic results of the modeling session; *abstraction activity* describes whether model creation has been performed via generation, classification, selection, or any combination thereof; *focus questions* describe how modeling was focused pragmatically or semantically using specific questions; *involved participants* indicate which persons or types of persons with specific skills or knowledge were involved in the FoCon; *instructions* describe the explicit or implicit instructions, guidance measures, procedures or conventions that have been provided to the involved participants; and *context* describes further situational aspects and constraints influencing the FoCon, such as used media, availability of resources, social issues, etc.

5.4.7.2 Coding Result

For the sample case, five FoCons have been identified. Each of these FoCons deals with a different topic of organizing and implementing a student's practical training in a healthcare institution:

1. Supervision procedure and cooperation with school
2. Reflection on mistakes during therapy
3. Documentation of and feedback on training experiences
4. Formal requirements on confirmation of training by hosting institution
5. Requirements on patient information process

The aims of the FoCons in general have been to facilitate common ground about the topics of discourse, and to create model representations of the involved people, their tasks and their interactions. The textual description of FoCons is too extensive to be comprehensively described here for the whole case. Two FoCons thus have been selected for demonstrating their qualities in the following:

FoCon 2: Reflection on mistakes during therapy

- *Timespan* (based on video timestamp): 03:50 - 10:00

- *Input*: Knowledge about permitted therapeutic activities, awareness of mistakes that can happen because of negligence or misconduct.
- *Outcome*: Awareness of the need to openly communicate mistakes during therapy and how to document them. The process of documenting mistakes and the circumstances that led to their occurrence.
- *Abstraction Activity*: Generation (of proposals for communicating and documenting therapeutic mistakes), selection (of actually implementable ways of communication and documentation)
- *Focus Questions*: Why is an open communication about therapeutic mistakes important in professional practice? How can mistakes be communicated in an open and constructive way?
- *Involved Participants*: Students (having no practical experiences in therapeutics and collaborative care taking), teacher (striving to convey the importance of openly communicating mistakes that might happen during therapeutic activities)
- *Instructions*: Identify the relevant communication and documentation tasks in case of a mistake. Represent those using the modeling language constructs and layout guidelines introduced earlier in the workshop.
- *Context*: This FoCon has been characterized by a dynamic discussion in its second half on in which form mistakes could and should be communicated to colleagues and team leaders.

FoCon 5: Requirements on patient information process

- *Timespan* (based on video timestamp): 20:00 - 31:09
- *Input*: Assumptions and knowledge about legal and social requirements on a patient information process distributed across the involved participants.
- *Outcome*: The desired outcome was to generate a fundamental understanding about the requirements on a patient information process. This process was represented as an interaction-oriented model of the work process.
- *Abstraction Activity*: Generation (of proposals for potentially relevant tasks and information items), selection (of actually necessary tasks and information items)
- *Focus Questions*: How should a patient information process be implemented? What are the legally required information to be passed on to the patient? Which social factors should be taken into consideration when interacting the patient?
- *Involved Participants*: Students (having no knowledge about legal requirements and regulations and no experiences in handling patients), teacher (aware of all legal requirements and regulations), supervising professional (experienced in conducting patient information processes)
- *Instructions*: Identify the relevant actors, tasks and information to be passed to the student. Represent those using the modeling language constructs and layout guidelines introduced earlier in the workshop.

- *Context*: Due to the FoCon covering the last in a series of topics discussed in the modeling session, concentration of the participants already was vanishing and discipline to adhere to the modeling guidelines was below optimum.

5.4.7.3 Observations regarding the sample case

The documented FoCons provide a rich picture of the content of the collaborative modeling session. The FoCons show that five distinct topics have been discussed during the modeling sessions. They also expose that the actors involved in the modeling session had different roles with respect to their knowledge about the topic to be modeled. In particular, the group comprised students of a healthcare profession, a teacher and an experienced professional. The instruction category shows that the process was supported procedurally by a facilitator and structurally by guidelines encoded in the modeling artifacts. The categories for input, outcome and focus questions differ between the FoCons due to their different semantic foci. In general, they show that the FoCons were specified targeting issues that might arise during the practical training of the students. Abstraction activities largely could be classified as generation and selection activities, whereas classification was rarely observed. This indicates that the actors were largely concerned with articulating proposals (generation) and discussing their validity (selection), whereas striving towards a more generic level of description of tasks during a practical training (classification) was not observed. The context dimension shows that the modeling process was affected by social effects among the actors (in particular in phases of selection) and the large number of topics covered in the session (which led to concentration issues in the final FoCons).

5.4.7.4 Limitations on coding and interpretation

FoCon-based coding requires to be able to exactly follow the content of the discourse among the actors. Model manipulation itself is not explicitly considered in the method. It is thus sufficient to be able to identify and content-wise understand the contributions of the actors involved in the modeling process.

5.4.8 Analysis based on complementary dimensions

Reviewing the coding results and interpretations shows that they partially offer complementary perspectives for analysis. The complementary aspects raise the question, whether value also can be generated from combining the perspectives of the different approaches. This section discusses findings that emerge from such combinations for the sample case on two examples.

The FoCon-based coding is the only approach that makes visible the different topics of discourse during the observed modeling session. Using the FoCons as an overlay for the timeline-based coding of the other approaches allows to identify the topics that were controversially discussed or have shown dynamic interaction patterns.

In combining FoCons with other approaches that consider the model creation dimension, it becomes obvious that not all topics of discourse were equally represented in the model. The modeling phase diagram makes visible five phases of substantial model manipulation. While those are basically aligned with the FoCons, only FoCons 2 (from 3:00 to 10:00) and FoCon 5 (from 20:00 to 31:09) show modeling activities that are spread over a longer duration in time. In addition, the CoPrA-based coding shows heterogenous participation of a large number of individuals or the whole group during these FoCons. The social modes of co-construction, however, do not show controversial consensus-building in these FoCons but rather elicitation and externalization activities. This indicates that a large number of actors have contributed their individual views during these FoCons not only in discourse but also by manipulating the model. Finding a common understanding, however, does not appear to have been difficult, but rather has been a unanimous combination of different viewpoints.

The combination of the pragmatic level coding used by Rittgen (2007) and CoPrA with the argumentative dimension introduced in the present chapter allows to identify, whether different kinds of contributions to the negotiation process show different qualities in terms of to which amount the contributions are grounded and qualified in the context of the modeling topic. Figure 5.11 shows the argumentative quality of "proposals" made during the observed modeling session. It shows that proposals were rarely made without any grounding or without specifying the scope of validity of the proposal (i.e., without "qualifying the proposal"). This indicates that contributions were well argued for, which in turn did not lead to major objections. Even during controversies (as visualized in the social modes of co-construction), the argumentative quality of proposal remained high.

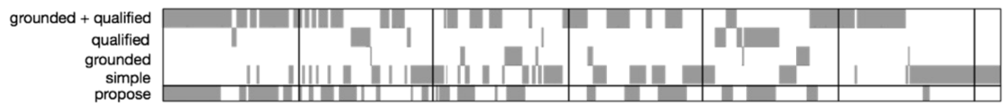

Figure 5.11: Example of combined analytical dimensions

Overall, the combination of the topic-oriented coding using FoCons with the activity-oriented segment-based coding adopted in the other approaches allows to draw much information from the raw coding results. Also, the combination of different perspectives used by the other approaches shows potential for deriving conclusions previously not identifiable when applying a single approach.

5.5 Implications

The implications of the evaluation results in the light of the chapter's objectives are discussed in the following. In showing the complementarity of the approaches, we outline the implications of considering articulation and alignment of actors' views about the topic of modeling as an aspect relevant for evaluation. Finally, we argue to work towards a combination of the of the approaches to allow for more comprehensive evaluation designs.

As has been shown in the study of related work, the five approaches reviewed above address different aspects of the modeling process. The evaluation of the sample case shows that each of the approach provides insights into features of a collaborative modeling process, which are not obtainable by any of the other approaches. In addition, the different granularities of analysis enable to describe the process of modeling on either micro- or macro-level. Figure 5.12 summarizes the different characteristics of the approaches using the structure developed in Section 5.2.

For each of the examined aspects (i.e. the links between *actor, group, model,* and *topic* in Figure 5.12), the analytical dimensions of the reviewed approaches and their complementarity are discussed in the following:

Model Manipulation by actors is described by Rittgen (2007) on a detailed level by distinguishing manipulations affecting model nodes and edges as well as the type of observable manipulation (e.g., add, remove, change). The approach presented in this chapter analyses model manipulations on a more aggregated level, only distinguishing the type of manipulation. The latter appears to be appropriate in cases, where a focused overview about the evaluation of the model is required for analysis. Still, this level of abstraction can be derived from the results of Rittgen (2007).

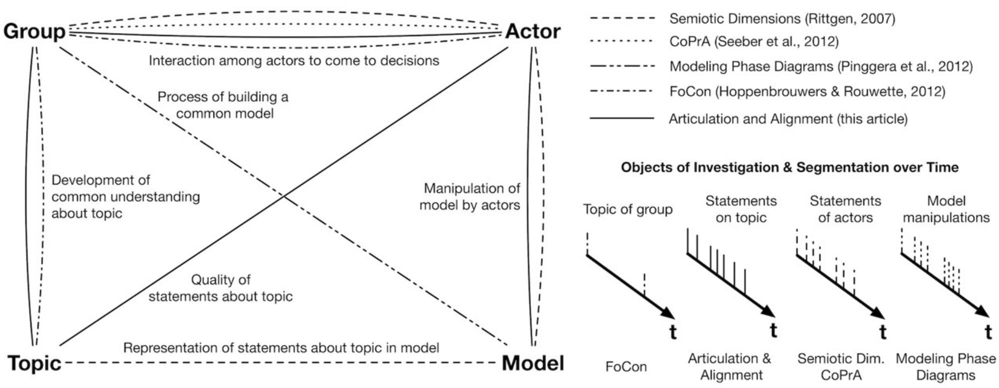

Figure 5.12: Complementarity of approaches for evaluation of collaborative modelling processes

The *interaction among actors to come to a decision* is the aspect addressed by the largest number of approaches in different dimensions. The participation of actors in group interaction is analyzed in CoPrA by considering the distribution of *individual contributions* of each actor. The active actors are identified, generating a detailed view on their interactions. The approach presented here uses an aggregated view and distinguishes activities by a single actor from those of a group. For analysis, CoPrA relies on splitting the modeling session in time segments of equal length, rather than the activity-based segmentation used here. Thus, both approaches show different aspects of individual contribution to modeling and augment each other. FoCon-based analysis also uses a similar observational focus, but only describes participation on FoCon-granularity. In contrast to the other approaches, it does not focus on the individual activities, but describes the roles, skills and knowledge of the active participants. Rittgen (2007) and CoPrA go beyond participation, and also analyze the statements actors utter to negotiate the models' content and its creation process. CoPrA here builds upon the data generated by Rittgen (2007) and further derives aggregated views and visualizations of activity distributions.

The *development of a common understanding about the topic* is addressed on different levels of granularity by two approaches. FoCon-based analysis content-wise captures the required input and desired outcome of each FoCon and also identifies the focus questions used to shape and direct collaborative discourse about the topic. It furthermore describes the type of abstraction activity used by the actors to find a common understanding and provides context to the analysis of the modeling session by describing the instructions, guidelines and constraints influencing the social interaction processes. The approach presented here focusses on how the group interacts on a fine grain level to align the understanding of the modeling topic. It distinguishes phases of elicitation and externalization from those concerned with different forms of consensus building.

The three remaining aspects are all only addressed by a single approach. The *representation of statements about the topic in the model* is covered by Rittgen's (2007) semantic level. It allows to map statements on the topic of modeling to be mapped to conceptual model semantics (such as fork, join, trigger, etc.). The *process of building a common model* is only addressed by Modeling Phase Diagrams. While this approach distinguishes different types of activities derived from observable model manipulations, it basically is agnostic about whether the model is created by an individual or a group. In the context of collaborative modeling, the identified activities thus always refer to the group as a whole. Still, this aspect might offer further analytical potential when examined with an approach that explicitly tries to identify group model building activities. This potential, however, has not been further explored in the present chapter.

The *quality of actors' statements about the topic of modeling* is only addresses in the approach introduced here and should be considered the main contribution of the chapter. This aspect is addressed in two dimensions. First, the epistemological dimension allows to analyze the point of reference for statement made on the topic. This allows to identify whether the model building activities are derived from a concrete, case-based level or from a more abstract perspective, which considers a generic business process with all its variants. This is valuable to determine, if a collaborative modeling process has achieved a sufficient level of abstraction for the respective goal of modeling. Second, it analyzes the quality the observed arguments with respect to whether they are grounded and qualified, assuming that the ability to ground and qualify claims about the modeling topic allows to draw conclusions about the maturity of the respective actor's understanding of the topic of modeling and its context.

While evaluating the quality of actors' statements about the topic of modeling provides value in itself, the results described in Section 5.4.8 and the complementarity of the approaches described in this section hint at a potential for further combining the different analytical dimensions and collecting data on different levels of granularity (c.f. Figure 5.12, bottom right). This could allow to analyze a single aspect of investigation more thoroughly. As an example, combining FoCons and the social modes of co-construction as described in this chapter to analyze development of a common understanding about the topic could show, which actors set elicitation activities in a certain role in the modeling process to facilitate the development of a common understanding. Furthermore, as indicated in Section 5.4.8, combining analytical dimensions of different aspects of investigation (such as the pragmatic dimension of Rittgen (2007) and the argumentative dimension proposed here) could allow to identify in-depth insights on how actors negotiate a common understanding and refine their own views about the modeling topic in the course of a collaborative modeling session.

Still, for deployment in practice, the relevant aspects of evaluation would need to be selected based on the objectives of the planned study. This calls for a structured approach for selecting appropriate dimensions and informing the data collection process. Such an approach is beyond the scope of the present chapter and will be subject of future research. The structure shown in Figure 5.12 together with the insights in planning evaluation processes described by Ssebuggwawo et al. (2013) could provide a starting point for the development of such an approach.

5.6 Conclusions

The field of the evaluation of collaborative modeling processes has shown significant progress over the last years. Current approaches focus on examining observable modeling activities or negotiation processes that show how actors agree on how to build a model. One aspect that has hardly been examined, is how actors come to a common understanding about their topic by means of modeling. However, literature on conceptual modeling quality argues for the importance of this aspect (Gemino & Wand 2003; Krogstie et al. 2006; Mayer 1989). The chapter has set out to fill this gap by introducing an evaluation approach that explicitly addresses articulation and alignment activities to develop a common understanding about the topic of modeling during the collaboration of the involved actors.

The major contribution of this chapter is to introduce an articulation- and alignment-perspective on the evaluation of collaborative modeling processes. This concept has been implemented in an evaluation scheme based on an existing approach adapted from the field of analyzing collaborative learning processes. As a side contribution, the chapter provides a comprehensive overview about the state-of-the-art in collaborative modeling process evaluation by comparing the proposed scheme with other approaches on an operative level and demonstrates their complementarity and combinability.

The research presented in this chapter has several limitations that need to be addressed in future research. On a conceptual level, the analytical dimensions of the proposed coding scheme require further validation from an articulation- and alignment-perspective. It is currently motivated from the concept of argumentative co-construction of knowledge (Noroozi et al. 2012), but should also be reflected against other approaches in this field, such as group model building (Zagonel 2002) or cognitive apprenticeship (Dennen & Burner 2008). The conceptualization of successful articulation and alignment being reached when a shared understanding about the topic emerges is challenged in recent research (Kolikant & Pollack 2015), which emphasizes the value of non-convergent collaboration for developing the actors' understanding of the topic. These results could inform a revision of the analytical dimension representing the observable social modes of co-construction. Second, the comparison with other evaluation approaches proposed in related work hints at the potential for a more comprehensive theoretical framework for evaluating collaborative modeling processes. These hints, however, are too immature and require more extensive empirical validation in terms of the applicability of the identified observational aspects on different types of modeling processes. Finally, the data analysis for the introduced evaluation approach is currently cumbersome to conduct, in particular when based on video recordings of collaborative modeling sessions. The approach would largely benefit from tool support, which should cover all phases of analysis, from the segmentation of source material and coding, to higher level analytics such as correlation analysis across the results in different dimensions.

The next research steps will focus on generating further empirical evidence on the applicability of the proposed methodology in further practical settings. These results will be used to determine analytical gaps and shortcomings of the current approach and allow for refinement of the evaluation scheme.

Acknowledgements

The author would like to thank Lucas Garzarolli and Gernot Hauser for conducting the coding activities necessary to perform the comparative analysis of the different evaluation approaches.

6 Supporting the collaborative construction of a shared understanding about work with a guided conceptual modeling technique[1]

6.1 Introduction

Human work in organizations is an inherently collaborative phenomenon. People rely on information or goods provided by others and in turn are required to provide others with the results of their work. In order to collaborate successfully, the involved people (*actors*) need to develop a shared understanding of how to interact in their work processes (Škerlavaj et al. 2007; Stary 2014) and to align their mutual expectations (Strauss 1988; Larsson 2003; Van Boven & Thompson 2003).

The development of a shared understanding is facilitated when the actors make explicit their individual views and create externalizations that can be used as subjects of discourse (Arias et al. 2000; Dix & Gongora 2011). Externalizations serve multiple purposes in this context, but most notably they support the individual articulation and reflection of one's view of their own work contribution (Seel 2003), serve as a boundary object between the collaborating actors when aligning their views (Arias & G. Fischer 2000), and provide a persistent point of reference usable during work implementation or future reflections (Adamides & Karacapilidis 2006; Kaghan & Lounsbury 2006; Roberts 2009).

Conceptual models have been widely used for years as externalizations of work processes (Rosemann et al. 2007). They are used to diagrammatically describe work using notational elements that are tailored to the work aspects to be represented (Giaglis 2001; Wieringa 2011). Conceptual models have already been used in earlier research to support the development of a shared understanding about work processes (Vennix et al.

[1] This chapter is identical in terms of content to the accepted final version of the article „Supporting the collaborative construction of a shared understanding about work with a guided conceptual modeling technique. Group Decision and Negotiation, in press. http://doi.org/10.1007/s10726-016-9485-7“. It has been modified to provide consecutive numbering of sections and figures throughout this thesis.

1996; Rittgen 2010; Niehaves & Plattfaut 2011; Aleem et al. 2012). Given the origins of conceptual modeling, most work in this area has been motivated from an information systems perspective (Curtis et al. 1992), and aims at creating or configuring IT-based systems for operative work, i.e., using them as a means for requirements engineering (Insfrán et al. 2002; Berki et al. 2004; Lai et al. 2014). Existing approaches in general assume that the contributing actors have existing modeling skills (Türetken & Demirörs 2011; Rittgen 2009a). Actors operatively involved in a work process, however, do not necessarily have these modeling skills (Frederiks & van der Weide 2006). One approach to address this challenge is to leave the task of model creation to an expert modeler (Dean et al. 2000; Herrmann et al. 2004). Existing psychological research, however, indicates that if actors themselves create models of their work, the process of modeling itself can be beneficial for the collaborative construction of a shared understanding (Dann 1992; van Boxtel & Veerman 2001; F. Fischer et al. 2002; Gao et al. 2007; Pirnay-Dummer & Lachner 2008). For this to happen, the actors need to be able to articulate individually their perspective on the work process in models that are mutually understood and serve as informational mediators among the involved actors (Dix & Gongora 2011). These different perspectives can then be combined and consolidated into a common model upon which all actors agree (Mullery 1979; Groeben & Scheele 2000; Rittgen 2007).

Utilizing the process of conceptual modeling in order to enable people operatively involved in the collaborative work process to develop a shared understanding about their work has not yet been addressed explicitly in the existing research. *The aim of the present work is to provide a methodology that offers structural and procedural guidance for conceptual modeling to support the collaborative construction of a shared understanding on collaborative work.* The research presented in this chapter was conducted following a design science approach (Hevner et al. 2004; Aken 2004). This chapter introduces a methodology as a design artifact, which supports the multi-perspective articulation of work processes. The rationale behind this method is to show the added value that conceptual models can provide in the process of creating a shared understanding about collaborative work. The contribution of this chapter is twofold: from a scientific perspective the chapter shows that collaborative conceptual modeling is a suitable means for making visible different viewpoints on work processes and aligning them to develop a shared understanding. From a practical perspective, the proposed methodology facilitates the process of creating a shared understanding via structurally and procedurally guided conceptual modeling. Research rigor is ensured by deriving the designed artifacts' requirements from the relevant literature in the fields of collaborative construction of knowledge, articulation support in collaborative settings, and collaborative conceptual modeling support. This brings together the research domains that are relevant for this work as described above. Consequently, evaluation in the present work focuses on assessing whether these requirements have been met. A multiple case study has been conducted to evaluate the designed method in its intended field of application, and to identify potential areas of improvement.

The remainder of this chapter is structured as follows: Section 6.2 reviews relevant prior work and identifies the requirements that need to be met by the methodology proposed in this chapter. Section 6.3 introduces "*Co*nfrontative *M*ulti-*P*erspective *Ar*ticulation and *E*licitation of *W*ork *P*rocesses" (CoMPArE) as the designed methodology. Section 6.5 describes the methodological approach used in the empirical study to analyze modeling workshops with respect to both process and outcome and in light of the objectives of the present chapter. It also summarizes the results of the study, which are then discussed and interpreted in light of the objectives. The chapter concludes with an account of the limitations of the chosen methodology and outlines further directions of research.

6.2 Related Work

Using collaborative conceptual modeling activities for creating a shared understanding about organizational phenomena has been addressed in several prior studies. The aim of the following literature review is to identify aspects that have been critical to the successful creation of a shared understanding via conceptual modeling in earlier work. Recently, research in the area of process modeling has started to include a consideration of the process of modeling (Claes et al. 2013; Soffer et al. 2012) and has identified the need for explicit support via guidance measures (Gassen et al. 2015). It has been recognized that the added value of collaborative modeling not only is generated via the resulting models, but also by creating common ground about the modeled process for the involved people (Hoppenbrouwers et al. 2005). Research has started to examine how these modeling processes can be facilitated to support the evolution of common ground (Hoppenbrouwers & Rouwette 2012). In this line of research, several efforts have been made to qualitatively describe the effects occurring in such modeling sessions (Rittgen 2007; Seeber et al. 2012). The modeling process is considered to be a series of negotiation acts, with the model being an artifact generated as an outcome. Support measures in the process of modeling consequently focus on enabling and documenting negotiation acts. The process of process modeling has also been examined from a cognitive perspective, focusing on the development of understanding on the subject of modeling for the individual modeler (Soffer et al. 2012), where the authors discuss the cognitive fit of available modeling constructs as a factor influencing the process of modeling. Other approaches focus on the process of model creation and collect their data solely from observing the manipulation of the model (Pinggera et al. 2012; Sedrakyan et al. 2014). They do not consider any aspects that do not have immediate impact on the model. Neither of these perspectives, however, facilitates observations of the process of creating shared knowledge about the modeled subject during the modeling process. This gap has already been identified by Gemino & Wand (2003), who suggest to evaluate modeling techniques based on models of learning. In this context, the research presented by F. Fischer & Mandl (2005) and Weinberger & F. Fischer (2006) provides a useful framework for discussion. They consider learning in collaborative settings to be processes of co-construction of knowledge, which can be mediated by external representations, such as conceptual models. In the following, we review approaches, that make use of external representations to facilitate the development of a shared understanding in collaborative work settings. We identify the fundamental concepts used to facilitate this process to provide input on how to support methodologically a collaborative modeling process.

In the area of business process modeling, the idea of enabling multiple actors to articulate and consolidate their individual understanding of their work contribution is the basis of the work of Türetken & Demirörs (2011). They propose a decentralized process elicitation approach ("Plural") in which individuals describe their own work. Plural is based on a multi-perspective modeling paradigm (Mullery 1979), which focuses on the representation of individual work contributions in models and subsequently merges them into a common model by agreeing on the interfaces among the individual models. It explicitly specifies the model elements which are subject to alignment, distinguishing them from the model parts that remain the responsibility of the individual actors. Similarly, Front et al. (2015) adopt multi-perspective modeling in the ISEA approach ("Identification, Simulation, Evaluation, Amelioration"). Perspectives here not exclusively refer to individual work contributions, but are understood as putting different aspects of an organization into the focus of observation (e.g., information, organization, interaction). Modeling is tightly integrated with means of simulation, which allows to evaluate the perceived correctness of the models and alter them accordingly.

Herrmann et al. (2004) propose a methodology, which does not rely on a standard modeling language but uses a language that is explicitly tailored to the needs of collaborative modeling by actors. This methodology ("Socio-technical walkthrough" – STWT) allows the creation of semi-structured and incomplete models. Workshops following the STWT methodology (Herrmann et al. 2007) target domain experts who do not necessarily need to have modeling experience, and as such the task of model creation is left to an expert modeler. The model itself acts as an artifact for discourse in the group of actors. The STWT uses SeeMe (Herrmann et al. 2000) as a modeling language, which comprises three core-modeling elements with context-sensitive semantics and is designed to represent models of socio-technical systems. It represents vague information, which explicitly captures disputed or unclear parts of a work process. The STWT strives to consolidate divergent views through moderation techniques directly in the workshop setting, and relies on a facilitator being responsible for making sure that all participants are able to contribute their views.

Collaborative modeling and negotiation are also promoted by the COMA approach (Rittgen 2009b), which focuses on providing support for articulating and consolidating models during collaborative modeling with a language-agnostic negotiation approach.

The COMA tool enables actors to communicate via the software in a structured way specified by the COMA methodology. Following its negotiation-oriented approach, COMA provides guidance for model consolidation (i.e., the negotiation process), which thus makes explicit divergent views and suggestions for a common view, which is ultimately agreed upon with the support of a human facilitator.

The four approaches mentioned above are conceptually similar to the approach introduced in the present chapter, as they all rely on collaborative conceptual modeling to facilitate the development of a shared understanding of work processes. Further research on creating a shared understanding via collaborative conceptual modeling has focused on examining how conceptual models can act as boundary objects (Arias et al. 2000) in collaborative settings and which requirements these models need to fulfill in order to be useable for actors in this context (Britton & S. Jones 1999; Genon et al. 2011). As will be discussed in the following, findings presented in research on these topics can provide valuable insights in how the development of a shared understanding can be supported via modeling.

The usefulness of multi-perspective modeling as proposed by Türetken & Demirörs (2011) based on Mullery (1979) has also been backed by results for cognitive sciences in the field of collaborative learning (Engelmann & Hesse 2010) and mutually revealing and understanding mental models (Groeben & Scheele 2000). Engelmann & Hesse (2010) show that sharing of individually created concept maps about a topic improves mutual understanding within a group and improves the group members' performance in terms of problem solving skills related to this topic. Groeben & Scheele (2000) propose to adopt a dialogical approach to create a shared understanding about mental models. They use a tailored conceptual modeling language to explicitly represent these mental models and make them a subject of dialogue that ultimately reflects the reached consensus.

In a similar line of research, Stoyanova & Kommers (2002) have examined the of use concept mapping as a means to facilitate shared cognition in learning. In their study they show that concepts are better understood by group members, when concepts maps are created in a shared setting. This provides the immediate opportunity to resolve different viewpoints. They also show that it can be beneficial for the learning outcome when the mapping process is guided by a moderator. F. Fischer et al. (2002) also report on similar results and focus in their study on the effects of content-specific mapping techniques, i.e., conceptual modeling approaches that offer a set of language elements tailored for the specific aim of modeling. They found in their empirical study that such tailored modeling languages encourage a more focused discourse and increases the quality of co-construction of knowledge as well as individual learning gains for the participants. Furthermore, they found that potential inconsistencies or incomplete information can be more easily identified and resolved in collaborative settings, when the concepts are explicitly represented visually in a shared environment. In the context of collaboratively drawn diagrams, Heiser et al. (2004) have identified similar phenomena. In their study, they found that the participants used gestures to mark areas of apparently divergent understandings and to outline potential resolutions. They also showed that – despite appropriate tool support for distributed settings – co-located modeling leads to higher quality problem solving.

Further research in the area of collaborative conceptual modeling has examined the role of facilitation and guidance in the process of modeling. Hoppenbrouwers & Rouwette (2012) propose to use "Focused Conceptualizations" (FoCons, (Hoppenbrouwers & Wilmont 2010)) to guide collaborative modeling processes. FoCons are instantiated as a guidance measure by providing a set of inquiry dimensions that might be considered relevant when discussing different topics in the course of a group model building process. Dean et al. (2000) have examined the effects of different group modeling approaches, and found that having participants work on separate parts of a single model increases individual involvement in contrast to traditional modeling chauffeured by a process analyst but leads to inconsistencies that need to be resolved in a separate step. These inconsistencies can be partially prevented when using a modeling approach that is guided by a human facilitator. Similar results have been observed by Hjalmarsson et al. (2015), who conducted empirical research in the area of facilitation of business process modeling workshops. They were able to identify different facilitation styles that are characterized by different behavioral patterns of the facilitator. The appropriateness of these styles is dependent on situational factors of the modeling setting and prior modeling knowledge of the participants. Gassen et al. (2015) recently have examined more closely the influence of the participants' modeling expertise on the appropriateness of guidance measures. Based on their findings, they advocate to adapt guidance measures dynamically to the participants' level of expertise. Recker et al. (2013) have shown that tool support for collaboration during modeling can help to gather and extend knowledge of participants about both, the modeled domain and the modeling method. Their results indicate that easy to use technology support is required for collaboration and modeling is required to enable participants to contribute.

Participants' level of modeling expertise in general, and how to address the prevalent lack thereof, when working with domain experts, has been a topic extensively addressed in collaborative modeling research. Pino et al. (2008) propose to bootstrap conceptual modeling with a storytelling approach, starting out with a case-based model and elaborating it in a separate step. A similar approach has been proposed by Fahland & Weidlich (2010), who present tool support to create models of different scenarios in a single process and propose an approach on how to derive a comprehensive process representation from these data. Also, the appropriateness of the used modeling language appears to have impact on the success of domain expert driven modeling. Malavolta et al. (2013) and Davies et al. (2006) have conducted studies on the requirements and expectations of practitioners on conceptual models in a business context. Both studies stress the importance of appropriate language semantics that serve the purpose supporting communication among stakeholders. Zugal et al. (2013) show that communication between domain experts and process analysts can be fostered during modeling by specifying test cases, which are appear to be easier to understand than fully elaborated process models due to their sequential nature. Kabicher & Rinderle-Ma (2011) propose to collect knowledge about work processes with representations resembling ToDo-lists to capture and document the actually performed work. They show how to use process mining techniques to extract process models from these data. Zarwin et al. (2014) in this context distinguish "formal modeling" from "natural modeling". The latter is claimed to better facilitate communication among stakeholders. They derive from literature that "natural" modeling should be based on intuitive symbols and constructs, that is should be collaborative, so that models can serve as vehicles of communication facilitating knowledge sharing and promoting negotiation and commonly agreed-upon decisions, and that modeling should be flexible in a sense that the symbols do not have a predefined meaning but rather the language used should emerge dynamically based on the situation at hand.

In summary, related work proposes diverse features for modeling approaches to facilitate the development of a common understanding via conceptual modeling. In the following, we have inductively derived those features from related work, which have been consistently identified in multiple, unrelated research efforts. The following list thus must not be considered to be exhaustive, but aggregates features that have been argued for to be relevant from different perspectives adopted in related work. For each identified feature, the related work described above that backs this claim is referenced again below. This related work is referred in the next section during the design of the modeling approach:

- **F1**: Individual understanding is codified in separate models by each actor and consolidated in a separate step ((Türetken & Demirörs 2011; Rittgen 2009b; Engelsman et al. 2010; Dean et al. 2000; Groeben & Scheele 2000))
- **F2**: Divergent understandings among the involved actors are identified and explicitly made visible ((Herrmann et al. 2004; Rittgen 2009b; Stoyanova & Kommers 2002; F. Fischer et al. 2002; Heiser et al. 2004; Türetken & Demirörs 2011))
- **F3**: The process of consolidation requires procedural guidance ((Herrmann et al. 2004; Rittgen 2009b; Dean et al. 2000; Hjalmarsson et al. 2015; Gassen et al. 2015; Hoppenbrouwers & Rouwette 2012; Stoyanova & Kommers 2002; Recker et al. 2013; Front et al. 2015))
- **F4**: The used modeling language must be adequate for the intended target group and appropriate for the aim of modeling ((Herrmann et al. 2004; Pino et al. 2008; Fahland & Weidlich 2010; Kabicher & Rinderle-Ma 2011; Zarwin et al. 2014; Malavolta et al. 2013; Groeben & Scheele 2000; F. Fischer et al. 2002; Davies et al. 2006; Zugal et al. 2013; Front et al. 2015))

When reviewing the four approaches pursuing similar objectives described above in the light of these properties, their different foci become clearly visible (cf. Table 6.1). Empty cells indicate that an approach does not explicitly give any account on how to consider the according property. The table shows that none of the mentioned approaches addresses all four feature requirements.

Table 6.1: Review of related work

	F1 - Individual modeling and collaborative consolidation	F2 - Explicitly mark different understandings during consolidation	F3 - Explicit procedural guidance for consolidation	F4 - Use of modeling language appropriate for domain experts
Plural	two explicitly distinguished steps	on level of interactions among roles		
ISEA			on abstract level, not detailed for modeling	use of "domain-specific, simplified languages"
STWT		via vagueness construct in SeeMe	via moderation techniques	use of SeeMe modeling language
COMA	possible, via propose/vote/merge	possible, via refering to them in negotiation	negotiation cycle embedded in tool	

Based upon the four given properties and the input provided by the related work identified for each of them, a modeling methodology can be specified in the next section. This methodology should explicitly address all four properties and guide actors to implement an according process of modeling work processes. Implementing such a methodology consequently is the major contribution of this chapter, as no available approach so far as considered all four identified factors for supporting collaborative modeling processes to create a common understanding about a collaborative work process.

6.3 Structural and procedural modeling guidance

In the following, we introduce *CoMPArE* as an approach for collaborative articulation and alignment of individual understandings about collaborative work processes. CoMPArE facilitates collaborative articulation of work processes using conceptual modeling techniques. As identified in related work, collaborative conceptual modeling is a recognized means to facilitate the development of a common understanding between people about a subject of discourse. The conceptual models serve as externalized artifacts representing the participants' mental models and so act as mediators for the development of a shared understanding (Groeben & Scheele 2000). The necessary properties identified in the former section are addressed in CoMPArE by offering structural and procedural guidance in a two-step modeling approach (cf. Figure 6.1). The first step makes sure that every involved participant is able to contribute his or her individual view on the work process (*F1*). The second step aims at avoiding the unreflected acceptance of inconsistent or conflicting views by explicitly confronting the participants with these issues (*F2*). Figure 6.1 shows a generic scheme for this process. The steps are described in the following in more detail.

The guidance measures aiming at facilitating alignment activities need to be integrated in the modeling approach (*F3*). This, however, cannot be done generically for all potential modeling languages. Work processes in organizations can be described with different foci (Curtis et al. 1992) that require conceptual modeling languages to provide different language constructs to describe appropriately the respective aspect (Krogstie et al. 1995). The used modeling language thus needs to be tailored to the targeted aspect of articulation (*F4*). It needs to provide constructs that allow a description of the relevant aspects of the work process.

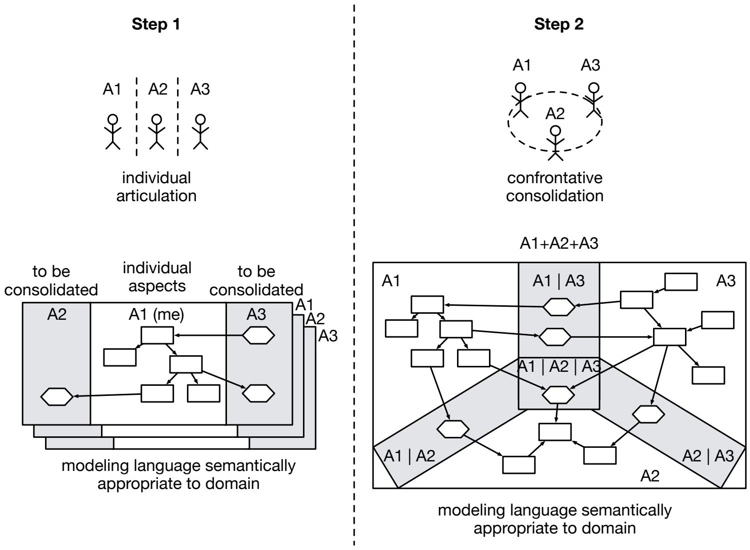

Figure 6.1: CoMPArE articulation scheme

Independently of the aspects to be represented, the language needs to adhere to certain structural requirements in order to facilitate alignment activities (cf. *F1* and *F2*). The modeling language can support the consolidation process by providing structural guidance. In line with the work of Türetken & Demirörs (2011), guidance measures are incorporated in the modeling notation in order to make visible the parts of the individual models that are subject to negotiation during the consolidation process, and which parts should remain the genuine responsibility of the contributing individual (cf. modeling areas and elements for modeling individual aspects and aspects to be consolidated in Figure 6.1).

As argued above, the intended purpose in the present case is to facilitate the collaborative construction of a shared understanding for people without any experience in modeling. The modeling language accordingly needs to be adapted to the needs of this target group.

6.3.1 Structural guidance via modeling language constructs and layout guidelines

Models of work processes that should express the collaborative aspects of work need to provide semantic constructs to represent who is involved in the work process, which activities are performed by the involved entities, and what information or artifacts are exchanged by them. These elements describe the coordinative aspects as well as the operative aspects of work and thus can be considered the minimal set of conceptual elements necessary to describe collaborative work (Fjuk & Dirckinck-Holmfeld 1997). When involving inexperienced modelers, it seems to be appropriate to limit the number of available modeling elements a priori to those appropriate for the intended modeling perspective and targeted outcome (Genon et al. 2011; Britton & S. Jones 1999). The modeling language proposed here consequently consists of the following three modeling elements: WHO–elements representing actors, roles, or organizational entities (exact semantics depend on the level of abstraction individually chosen for modeling), WHAT–elements representing activities, and EXCHANGE-elements describing the exchange of information or artifacts among WHO-elements (exact semantics depend on designator for element).

The modeling elements identified above are put into mutual relationships by spatially arranging them as follows: Each WHAT-item is assigned to a WHO-item by placing it on an imaginary straight line originating from the WHO-item. The causality between WHAT-items is expressed by their order on the line, starting with the one that is placed nearest to the WHO-item EXCHANGE-items are placed in-between the lines of the communicating WHO-elements and are causally related in the stream of WHAT-items by placing them between the activity in which or after which the exchange is triggered and the activity that receives or is triggered by the exchange.

The EXCHANGE-items act as the primary subjects of negotiation, as they are used to couple the individual models. WHO-items can also be the subject of discourse during consolidation in step 2. Inconsistencies within the WHO-items, however, hint at fundamental differences on how the process is perceived by the involved participants and might require more comprehensive negotiation activities (cf. Section 6.3.2.2 - collaborative consolidation). WHAT-items remain the responsibilities of the contributing participants, as they should only describe individual activities.

The use of the proposed methodology with the outlined modeling language is described more extensively in (Oppl & Alexopoulou 2016). It has been embedded in an approach to facilitate the elicitation of business process knowledge in this chapter and is linked with means for technical interpretation of the resulting models.

6.3.2 Procedural guidance for confrontative model articulation

In the following sections, we describe the two articulation steps of CoMPArE when used for the articulation and elicitation of the procedural and collaboration aspects of work processes by inexperienced modelers.

6.3.2.1 Individual Articulation

Step 1 focusses on the individual articulation of the participants' own perceived work contributions. Multi-perspective modeling relies on the ability to consolidate individual viewpoints to a common model. Modeling participants can independently of each other describe WHAT they do to contribute to the work process - i.e., their own activities, and with WHOM they EXCHANGE information or artifacts - i.e., the actors or organizational entities they are interacting with and how this interaction manifests in information or artifact exchange.

Figure 6.2 shows three individual models created for a sample collaborative work process concerned with filing a request for vacation in a company. This example will be used to illustrate the results of the different modeling steps. The vacation request process involves three actors: an employee (requesting vacation), a secretary (checking for conflicts and filing requests), and a manager (deciding upon requests). All models represent, what the participants think they are doing (red elements), who they think they need to collaborate with (blue elements), and what they think they need to exchange with their collaborators (yellow elements).

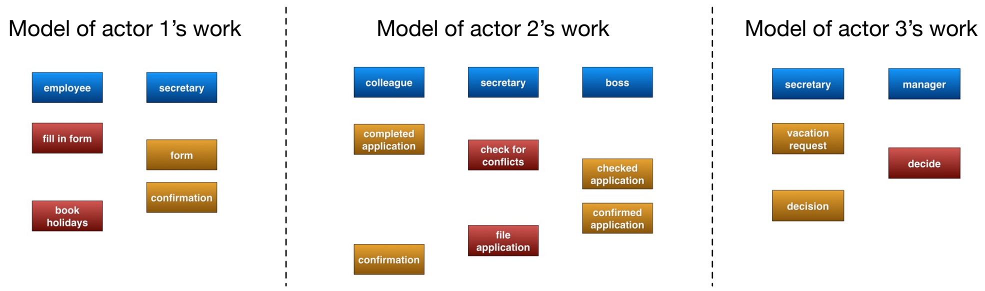

Figure 6.2: Individually articulated model

As can be seen in Figure 6.2, perceived interaction might differ in quality from the sender's and receiver's perspectives, respectively. "Form" in actor 1's model and "completed application" in actor 2's model not only use different wording but refer to different concepts, the latter stressing the importance of a completely filled application form, which is not explicitly addressed in actor 1's model. Such differences are the triggers for consolidation, which is facilitated in the next modeling step.

6.3.2.2 Confrontative Consolidation

Consolidation has to make visible and keep track of different perceptions of how to implement the collaborative work process. The individual models are thus merged and aligned according to the following scheme. Figure 6.3 picks up on the example presented in the last sections and illustrates a sample consolidation process for two participants. The consolidation process follows a specified procedure, which is introduced by the facilitator.

One of the modeling participants starts by placing the WHO-items on the upper border of the shared modeling surface. The actor responsible for starting the real-world work process (if known a priori) consequently should start modeling *(cf. step 1 in Figure 6.3)*. The same modeling participant continues to describe their own contribution to the work process by placing WHAT-items below their own WHO-item. Others do not intervene during this stage *(cf. step 2 in Figure 6.3)*.

As soon as the modeling participant encounters the first EXCHANGE-item *(cf. steps 3-4 in Figure 6.3)*, the targeted communication partner (acting as the source or the sink of the exchange) steps in and starts by matching their own perception of the work process with the already externalized model *(cf. steps 5-7 in Figure 6.3)*. If a match has been identified or different understandings have been resolved to form a match, the modeler responsible for the targeted entity continues to complete the model with the elements describing how he/she contributed to the work process until the agreed upon point of collaboration (i.e. the EXCHANGE element). This includes adding their own WHO elements.

Consolidation continues in this way until all points of collaboration are agreed upon. If one actor has completed his or her contribution, others with remaining elements not yet incorporated in the common model take over and provide further input to the consolidation process *(cf. steps 8-12 in Figure 6.3)*.

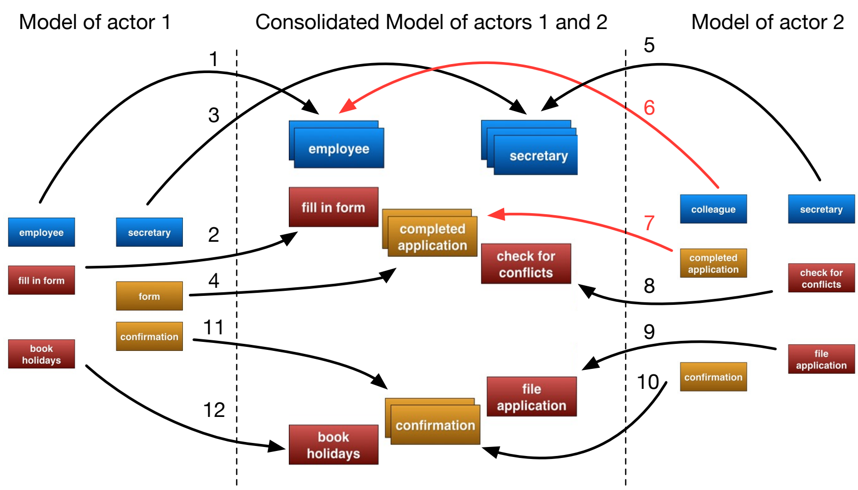

Figure 6.3: Consolidation process

During the process of consolidation, the participants are confronted with mismatches in the individual models. Such mismatches are identified, whenever elements representing aspects addressed in different individual models should be merged in the course of building the common model. Mismatches can occur in different forms: A fundamental mismatch occurs, when a negotiable element (e.g., the WHO- and EXCHANGE-elements in the modeling language used in Figure 6.3) are only provided by one participant and cannot be matched by an according element of the intended communication partner. A semantic mismatch occurs, when matching elements basically can be identified but bear labels with different semantics, indicating the need for aligning the understanding of the represented concepts (e.g., the actual content of a document represented by an EXCHANGE-element).

Semantic mismatches can be found, when individual models created on different levels of granularity are matched or when different naming has been used to describe the same concept (e.g., for WHO-elements “boss” and “manager” in the sample process depicted in Figure 6.2). Another example of a semantic mismatch can be found in the sample process, where the EXCHANGE-items “form” (offered by actor 1) and “completed application” (expected by actor 2) indicate that actor 2 has more specific expectations on the exchanged information than actor 1, while their fundamental intentions do not differ. Such cases require a clarification of the specific form or content of EXCHANGE-items. An example for a fundamental mismatch can be found the sample case, actor 3 offers an EXCHANGE-items “decision” which is not expected by actor 2. Actor 2 has built its process around the expected EXCHANGE item “confirmed application” which is of fundamentally different nature and thus cannot be matched without explicit consolidation activities.

Such mismatches are triggers for collaborative construction of a shared understanding (Roschelle 1992), which ultimately should resolve the mismatch. The involved people refine and alter their mental models to converge to an extent that allows a common understanding on how to collaborate to be reached (ibid.). These convergence processes can occur implicitly or explicitly. The impact on the individual participants’ understandings can be expected to be more fundamental, when mismatches are explicitly addressed and are resolved consensually (Weinberger & F. Fischer 2006). Consequently, explicit resolution is intended to be encouraged in the methodology by explicitly asking the participants to place matching elements on top of each other, thus confronting them with evident mismatches in the individual models.

Figure 6.4 shows the consolidated model for the sample process. The matching WHO- and EXCHANGE-items are placed on top of each other, making the agreed upon aspects of the collaborative work process immediately visible. The mismatch in between “boss” and “manager” has been resolved by agreeing on the term “boss”. The mismatch between “form” and “completed application” has been resolved by having the employee commit to only submit application forms without any missing information. The mismatch triggered by “decision” not expected by the secretary and “confirmed application” not provided by the manager has been resolved by having the participant representing the manager agree that the common model in its current version should cover only cases, where applications have been positively evaluated. Full consensus, however, cannot necessary be assumed here, as the manager still "decides" upon rather than "confirms" a vacation request.

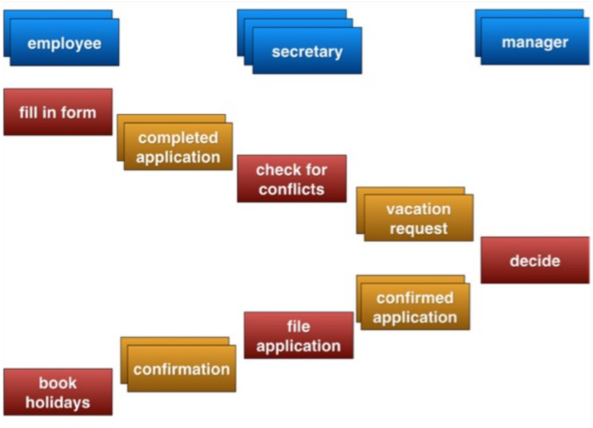

Figure 6.4: Consolidated model

6.3.3 Fulfillment of required properties

We have identified four properties of modeling approaches, which should support this process, and designed the modeling approach accordingly. *F1*, in which individual understanding is codified in separate models by each actor and consolidated in a separate step, has been met by introducing a dedicated individual articulation session, which requires each participant to articulate his or her own view on the work process. In the collaborative step 2, all process participants are required to contribute and explicitly explain their own inputs. In order to meet *F2*, in which divergent understandings among the involved actors are identified and explicitly made visible, the individual contributions during consolidation are not only made orally, but are codified in modeling elements and element ensembles (element matching), to make them visible during the consolidation activities. *F3*, in which the process of consolidation requires procedural guidance, has been realized by specifying consolidation guidelines on top of the structural guidance measures. The unreflected acceptance of different understandings is prevented by the consolidation methodology, which requires points of collaboration to be matched explicitly between the interacting partners. Mutually matching model elements should be available for each collaboration, if it is expected by both parties. If this is not the case, the model elements cannot be matched and explicitly point at potentially divergent mental models, which need to be aligned either in terms of which concepts to use to describe the work process or in terms of expectations on the collaboration performed during the work process. *F4*, in which the used modeling language must be adequate for the intended target group and appropriate for the aim of modeling, has been instantiated for the target group of operative people without conceptual modeling experiences, as is required for the present instantiation of the CoMPArE articulation scheme. The modeling language has been designed to represent concrete work cases, as evidence in existing research (e.g., (Kabicher & Rinderle-Ma 2011; Lai et al. 2014; Santoro et al. 2010)) shows that people inexperienced in conceptual modeling are better capable to develop an understanding of the concepts necessary to describe a work process in this way. To make the notation more accessible for inexperienced modelers, it was limited to three elements with generic semantics suitable to model collaborative work processes. The limited number of elements (Genon et al. 2011; Muehlen & Recker 2008) and their interpretable semantics (Zarwin et al. 2014) appear to contribute towards this ends.

The aim of the designed artifact is to introduce a method that provides structural and procedural guidance for addressing the above mentioned issues and thus to enable the construction of a shared understanding on a collaborative work process. Whether or not the application of the methodology reaches these goals has been evaluated in extensive empirical studies. The following section describes the empirical approach, summarizes the evaluation results, and discusses them in the light of the objectives of this chapter.

6.4 Empirical Validation

The aim of this section is to demonstrate how CoMPArE is used by operative actors to construct in a collaborative manner a shared understanding of their collaborative work processes. This implies the existence of a shared work context in which different views in collaborative work can emerge. This shared work context, however, cannot be controlled or artificially created, as would be necessary for an experimental setup. Case study research (Yin 2009) thus remains a suitable validation strategy. The following paragraphs describe the fundamental research design for validation of the proposed concept. They are structured along Yin's components of research design for case studies.

The following *research question* can be derived from the aforementioned aim as a starting point for the empirical design: *Does the modeling approach facilitate the collaborative construction of a shared understanding about a work process?*

The case study this work reports on strives to provide answers to this question. This is concretized by a *proposition*, which has already been discussed in Section 6.2: *Confrontative consolidation of multi-perspective models leads to explicit engagement with the disagreed aspect and facilitates the collaborative construction of a shared understanding of the overall work process.*

6.4.1 Methodology

CoMPArE is not restricted to a particular professional domain but aims at facilitating the collaborative construction of a shared understanding about work processed in a generic way. A multiple-case design is necessary in order to validate this claim. The cases need to be selected from different professional domains, reflecting the diverse range of the potential backgrounds of the participants.

The *unit of analysis* for the case study is a group working together in the course of a single modeling workshop. The units of analysis call for an *embedded case-study design*, in which the relevant aspects of the cases are examined coherently using the same set of empirical methods for each case. In the following, we describe the empirical methods selected for assessing the research proposition. Selection of the methods is based on the requirements on data collection identified above. The *assessment of the research proposition* requires data that show the relationship between interaction among the involved people and articulation activities. The interaction among people during the *articulation process* needs to be assessed with respect to the evolution of an agreement that the common model adequately represents the collaborative work process. Furthermore, the *perceived adequacy of the created representation* needs to be examined.

Evaluation of the articulation process

The aim the proposed modeling approach is to facilitate the alignment of different viewpoints on how collaborative work is implemented in organizations. The proposed collaborative articulation approach facilitates a process of collaborative construction of knowledge about work processes, and it involves all actors that are participating in the respective workshop. The effects observable during such a process can be assessed by applying a variant of discourse analysis proposed by Weinberger & F. Fischer (2006) adapted to collaborative modeling settings. In the following, we briefly describe the dimensions along which the collaborative modeling process is analyzed.

The *participation dimension* refers to the amount of contributions made by the actor. This includes two aspects: the quantity of participation for each actor and the heterogeneity of participation, i.e. the amount of turn taking happening during the modeling process. Participation is not limited to utterances (verbal or written, depending on the source of the analyzed material) but also includes manipulations of the model. During analysis, the actually involved persons are identified for each observed activity.

The *epistemic dimension* refers to the quality of contributions made by the actors. The following scheme is used for classification: An initial distinction is made between on- and off-task statements. Off-task statements comprise all statements which are content-wise not related to the topic of modeling. On-task statements are distinguished based on their content. Following Weinberger & F. Fischer (2006), statements can refer to: (a) the problem space. Statements in this category refer to the concrete case that is currently articulated or discussed; (b) the conceptual space. Statements in this category refer to generalizations of a concrete case and cover theoretical considerations about the generic aspects of the current issue; (c) the relationships between problem and conceptual space. Statements in this category link case-specific and generic statements; and (d) the relationships between the problem space and prior knowledge. Statements made in this category link case-specific statements to prior knowledge of an actor.

The *argumentative dimension* focusses on observable contributions to problem inquiry and resolution. In a first analytical step, claims made by the actors are identified. Each contribution either constitutes a non-argumentative move or an argumentative claim. Claims can be qualified or grounded. Actors explicitly limit the validity of qualified claims validity through describing the context in which the claim is assumed to be valid. Grounded claims are argumentatively backed by the actors through further justifications, which explain why they are assumed to be valid. Claims can also have both qualities, or exhibit neither of them. The latter cases are considered "simple claims".

The final dimension of the original approach addresses the *social modes of co-construction*. It classifies the observed discourse with respect to how the actors as a group create align their understanding about the topic and formulate arguments together. Discourse that contains content referring to the topic of modeling (as identified in the epistemic dimension) here is distinguished into externalization, elicitation, and consensus-building activities. Externalization refers to units during which actors contributes its own view on the current topic of discourse. Elicitation activities refer to actors questioning others or provoking reactions. Consensus-building can again take different forms. Their identification is described in detail in (Weinberger and Fischer 2006) and summarized in the following: In "quick consensus building", contributions of one actor are accepted by the group implicitly or explicitly without any modification and any "indication that the peer perspective has been taken over" (Weinberger & F. Fischer 2006) by the other learners. Quick consensus-building does not give any indication, if knowledge alignment has taken place. "Integration-oriented consensus building" means that actors take over positions of other actors and extend and validate these positions with own input. A unit rated in this category must show statements that "significantly differ(s) from a juxtaposition of perspectives, but indicates a further development of the analysis" (Weinberger & F. Fischer 2006) by an actor. "Conflict-oriented consensus building" is characterized by actors, who not accept contributions of others as they are, but challenge. They require adaptation of the articulated positions in order to achieve a common understanding. Units that should be rated in this category are indicated by "rejection, exclusion or negative evaluation of peer contributions" (Weinberger and Fischer 2006), either explicitly or implicitly by ignorance or replacement of a contribution.

The *modeling dimension* describes model manipulations performed by the actors. These manipulations can take different forms, which are informed by those described by Rittgen (2007) for the syntactic level of modeling analysis: (a) adding elements to the model, (b) changing the layout of the model (i.e. rearranging elements), (d) merging duplicate modeling elements or removing them (which is common, when actors contribute individually prepared model elements to a shared model).

These dimensions address different aspects of how people reach a common understanding about a problem. In the context of the CoMPArE evaluation, the participants' contributions are classified along these dimensions. If the research proposition was valid, the discourse analysis should confirm the following propositions about the workshop process (structured along the analyzed dimensions): *Participation* shows involvement of multiple participants. Heterogeneity does not contribute to the assessment of the proposition, as the amount of expectable engagement is dependent on the involvement in the actual work process. *Epistemic perspective* mainly shows statements about the problem space (i.e. the actual work case reflected upon). Statements about the conceptual space (i.e. the development of a generic view on a work process) could be observable but are not necessarily to be expected, as the proposed method does not facilitate abstraction. *Argumentative claims* should be grounded and/or qualified whenever a conflict in EXCHANGE- or WHO-elements is discovered and resolved in the model during collaborative consolidation. Simple claims are to be expected during the articulation of individual views that are not questioned by others. In *Social modes of co-construction*, externalization and elicitation are prevalent when individuals contribute their views on the work process, potentially interrupted by elicitation intervention by others. Whenever conflicts in EXCHANGE- or WHO-elements are discovered, consensus-building activities are observable.

For analysis of the cases, the categorization results are visualized diagrammatically along a timeline with all categories stacked on the y-axis clustered by dimension (cf. Figures 6.5, 6.6 and 6.7). This allows for identification of relationships between the dimensions and enables interpretation of the observed behavior with respect to the construction of a shared understanding.

Evaluation of the perceived outcome and support

The evaluation of the proposition requires a consideration of the participants' perceptions about the approach's adequacy to facilitate the development of a shared understanding about the work process, and the adequacy of the modeling result with respect to the individually perceived work processes. A feedback questionnaire was designed to assess the outcome of the assessed workshops, as the large number of participants made individual in-depth interviews infeasible. The items of the questionnaire were chosen to cover aspects of collaboration, facilitation and shared understanding as contained in the proposition. The items were formulated based on prior existing work in these areas (Gemino & Wand 2004; Kolfschoten & De Vreede 2009; Krogstie et al. 2006; Recker et al. 2013; Sedera et al. 2002) (cf. Appendix in Section 6.6) and tested in two dedicated pretest-workshops for understandability in the target group. A revised version of the questionnaire with items re-formulated for increased understandability was then translated into the native languages of the workshop participants. Those translated questionnaires were consistently used throughout all workshops.

Following the individual aspects of the research proposition, the questionnaire provides items targeting (1) the perceived relevance and usefulness of the articulation process, (2) the perceived articulation outcomes, and (3) the adequacy of support during the articulation process. The items, which are listed in detail in the Appendix in Section 6.6, were rated on a five-point Likert scale, and were complemented with open questions to allow for free-form feedback and articulation of impressions.

For quantitative analysis, the items of the questionnaire have been aggregated to constructs that operationalize the propositions. The following list gives an overview about these constructs (cf. Appendix in Section 6.6):

- Relevance and usefulness of articulation process: *P-Rel* relevance of articulation process, *P-Use* usefulness of articulation process
- Perceived articulation outcome: *O-Use* usefulness of workshop outcome; *O-Rel* relevance of workshop outcome; *O-LearnCom* learned about interaction; *O-LearnTop* learned about the topic
- Support of articulation process: *S-Comp* complexity of tasks during workshop; *S-Underst* understanding of tasks during workshop; *S-Stress* perceived stress during workshop; *S-Easy* ease of task implementation; *S-Facil* facilitation through workshop setting

In order to confirm the formulated propositions, the corresponding constructs (as identified above) should show a value that is significantly ($p<0.05$) better (i.e., lower) than the scale's median value of 3. Potential differences between the cases should become visible in significantly ($p<0.05$) different values for the constructs.

6.4.2 Results

This section reports on the results of the empirical validation carried out in a multiple case-study. We first report on the process of data collection, outline the selected cases, and argue for their suitability for a multiple case study design. We then describe each case with respect to its context and the results of the empirical methods described above. The section concludes with a summary of the results reviewed across the different cases.

6.4.2.1 Data collection

The selected cases have all been carried out in the course of vocational training programs that were conducted in the context of the European Union-funded Leonardo da Vinci Project (FARAW; http://www.faraw.eu). Overall, 12 workshops have been documented using the methodology described above, and 175 participants provided answers to the questionnaire used for assessing the perceived outcome of the CoMPArE applications.

The aim of all documented workshops was to provide operative personnel with initial experiences to explicitly reflect on their daily work practices and their collaboration with others. Still, they differ along different dimensions. First, the *professional background of the participants* differed fundamentally. Five workshops were conducted in process-centric production industry with participants used to collaborative work organized along flows of material. Seven workshops were conducted in interaction-centric work settings such as healthcare or social work, were participants are used to plan their work ad-hoc in alignment with perceived requirements of other people. Second, the workshops different in the *amount and quality of support by a human facilitator*. Six workshops were facilitated by people having participated in a facilitator's training, who repeatedly urged participant to use the structural guidance measures described above. Four workshops were facilitated by people having acquired their knowledge about the methodology from textual descriptions. Their facilitation approach in general was more laisser-faire, initially pointing at the structural guidelines but accepting their violation at least to some extent. Two workshops were facilitated by people having received only a brief introduction to the approach, who did not point out any of the structural guidelines when introducing the participants to their task. Third, the workshops differed in the *perceivable added value of their outcome*. In five cases, the participants were not given any indication of the potential impact of their collaboratively created model. In two cases, the participants were explicitly told that their results would be the basis of the future implementation of the respective work process in the whole organization. In the remaining five cases, the participants were told that the results of the workshop should support them in their individual future work. Three cases have been selected out of the 12 documented cases, representing diverse characteristics along all three dimensions. These characteristics are summarized in Table 6.2 for each case. The cases are presented in detail in the following to give an in-depth review of the effects of CoMPArE. The CoMPArE workshops were video-taped for later analysis of the articulation and reflection processes. The modeling results in all steps of the methodology were documented as photos. After the participation in the CoMPArE workshop, the participants were asked to complete the questionnaire assessing the perceived outcomes, as described above.

The first case was conducted in an Austrian vocational training school for adults being educated as carers for the elderly. As a part of their education, the students have to complete several internships in long-term care institutions. The first day of these internships is of special importance, as organizational and administrative details are clarified on this day between the students, the care-homes, and the school. The head of the vocational training school observed uncertainties and ambiguities regarding the mutual expectations and requirements of what was to happen on this first day. CoMPArE was used to articulate experiences and expectations by all involved parties and create a shared understanding of what should happen on this day. No account was given on what would happen with the results of the workshop. It was conducted by 11 participants working in two groups. The age of the participants ranged between 22 and 47, and eight participants were female and three were male. All participants had a background in healthcare, and none of them had any experience working in conceptual modeling. The workshop was held on a single afternoon, with three hours of active work. The workshop was facilitated by two trainers of the vocational training school, who had participated in a CoMPArE facilitator-training event previously. They still adopted a laizzer-faire approach to facilitation, not enforcing the structural guidelines.

The second case was documented in a workshop carried out in the context of a training session on shop-floor logistics in an industrial production company in Slovenia. The participants were tool-makers, who are concerned with producing and maintaining tools for flexible manufacturing cells. Starting from raw materials, the production, assembly, and maintenance of these tools require multiple steps using different machinery distributed all over the production shop-floor. The tool-makers normally are assigned to one single step in the work process and do not have an overview about the overall process and how their contribution affects the work of others. The aim of CoMPArE was to create awareness of how one's own work is embedded in the overall process, and how coordination and collaboration potentially could be improved. This aim was also communicated to the participants. Eleven participants contributed to the workshop reviewed in this case study, all of whom were male and with an age range of 16 to 21. They all had practical experiences in the work process to be reflected upon and were engaged in a sample implementation of the process preceding the CoMPArE application. In the sample implementation, the participants distributed their roles in the production process and produced a tool holder for a robotic arm. The workshop was facilitated by a foreman, who also was responsible for the company's training-on-the-job program. The foreman was a domain expert (i.e., was a tool-maker himself) and had participated in a CoMPArE facilitator training program previously and repeatedly urged the participant to adhere to the structural guidelines.

Case 3 was taken from a series of workshops conducted in a vocational education school for social workers in the Netherlands. Similarly to the care-workers in case 1, the students spend part of their education in practical trainings in real social-work institutions. The students had spent their internships at different institutions, but all had implemented the same task. Consequently, they shared a common work context but had made different experiences from practice. The aim of the implementation of CoMPArE was to articulate and reflect upon experiences and lessons learned in order to create documentation of what is important when organizing such an event with the involvement of clients. The students were told that the results would directly impact the organization of future practical trainings. The 7 participants aged between 20 and 24 and had completed the second year of their three-year educational program. One of them was male whilst the remaining six were female. None of them had any experiences in conceptual modeling. The workshop facilitators were social workers themselves, being active as domain expert teachers in the school. They had not participated in a CoMPArE-facilitator training session before their workshops, but conducted their workshop implementation based on a textual description of the methodology. They did not introduce any of the structural guidance measures but only explained the meaning of the modeling elements.

Table 6.2: Comparison of cases along dimensions

	Dimension		
Case	*Professional background*	*Quality of facilitation*	*Perceivable added value*
Case 1	interaction-centric	laizzer-faire	none
Case 2	process-centric	strict	individual learning
Case 3	interaction-centric	none	organizational impact

6.4.2.2 Summary of Articulation Process

The recorded collaborative confrontative session for case 1 lasted 35 minutes and 10 seconds (cf. Figure 6.5, left). In this duration, 28 segments were identified with lengths ranging between 20 and 255 seconds (median = 50 sec). Two of these segments contain off-topic interactions (as identified as part of the epistemic analysis), overall lasting one minute).

The discourse analysis for case 1 depicts a process which is representative for workshops that are facilitated following the methodological steps for confrontative consolidation. The low amount of consolidation activities during modeling (e.g. matching model elements and removing duplicates), however, was not expected given that element consolidation is an integral part of the methodology when specifying the interfaces among the participants of the work process. In the present case, the lack of consolidation activities can be attributed to the behavior of the participants, who used different levels of detail when describing their work contribution and interaction, which led to complementary rather than conflicting EXCHANGE-elements.

The recorded collaborative confrontative session for case 2 lasted 21 minutes (cf. Figure 6.5, right), during which 15 segments were identified with lengths between 40 and 210 seconds (median = 60 sec). No off-topic discourse was identified, and the entire session was dedicated to discussing the work process.

The discourse analysis for case 2 depicts a process which is representative for workshops that focus on work processes in which the implementation of the work tasks is known a priori and the interfaces among the participants are clearly specified. Similar results have been observed in all other cases that were observed in the domain of industrial production. As in case 1, the low amount of consolidation activities is not to be expected from a methodological point of view. In the present case, this can be attributed to the facilitator, who strictly followed the structuring guidelines, but only accepted one single card for each model element already during articulation (i.e. in macro-segment 1) and omitted matching cards for reasons of clear visualization.

The recorded collaborative confrontative session for case 3 lasted 35 minutes and 40 seconds (cf. Figure 6.6, left), during which 12 segments were identified with lengths between 45 and 255 seconds (median = 187.5 sec). Two of these segments contain off-topic interactions (as identified as part of the epistemic analysis), overall lasting seven minutes and 10 seconds.

The discourse analysis for case 3 shows that the process in this workshop has been less structured than in the other two cases. The suggested layout for model creation was ignored in this case, as was the phase of individual articulation. Both aspects can be attributed to a lack of methodological guidance by the facilitator. Still, the fundamental phases proposed for consolidation are visible in the analysis of the present case.

When reviewing the articulation processes of the three cases, it is useful to compare them on the level of different modeling phases identifiable in the workshops. These phases not only show similar content focus across all cases, but also expose similar interaction patterns, and be described and discussed in more detail in the following. Figure 6.6 (right) gives an overview about the four identified phases.

The first phase has been named "agreeing on the scope of the process" and is the only one that is present in just a single case. This can be attributed to the fact that the scope of the process has not been fully clear upfront in case 1. In the other two cases, the participants had a coherent image of where the process to be reflected upon starts and ends. This phase is characterized by a high number of active participants who largely engage in case specific elaboration on the scope of the process on a rather heterogeneous level of argumentative quality. The interaction focused on externalization and elicitation activities, with consensus building activities at the end of the segment.

The second phase in all three cases was dedicated to describe the individually articulated model parts and contribute them to the overall model. This phase is characterized by adding the elements to the shared model. In cases 1 and 2, single participants contribute their elements largely without any interventions by others. This is different for case 3, where this macro-segment shows involvement of up to four participants per segment. Also, the argumentative quality does not reach the quality of cases 1 and 2, and largely remains on the level of simple, ungrounded, and unqualified claims.

Phase 3 in all three cases started after the initial model articulation finished and is concerned with revisiting and discussing the model that was just created. It is characterized by little to no new content being added to the model, but largely focusses on rearrangement activities. Participation in general is higher than in the former phase (with case 3 being an exception, as participation had already reached a high level in the former phase). In all three cases, contributions from an epistemic perspective have shifted to a more generic perspective, abstracting from the discussion of single cases. A relatively high amount of consensus-building activities (in comparison to the former phases) can be observed. Case 2 is an exception here, as during its brief duration, it remains at the level of externalization and elicitation, i.e., the rearrangements made by participants were not questioned by others.

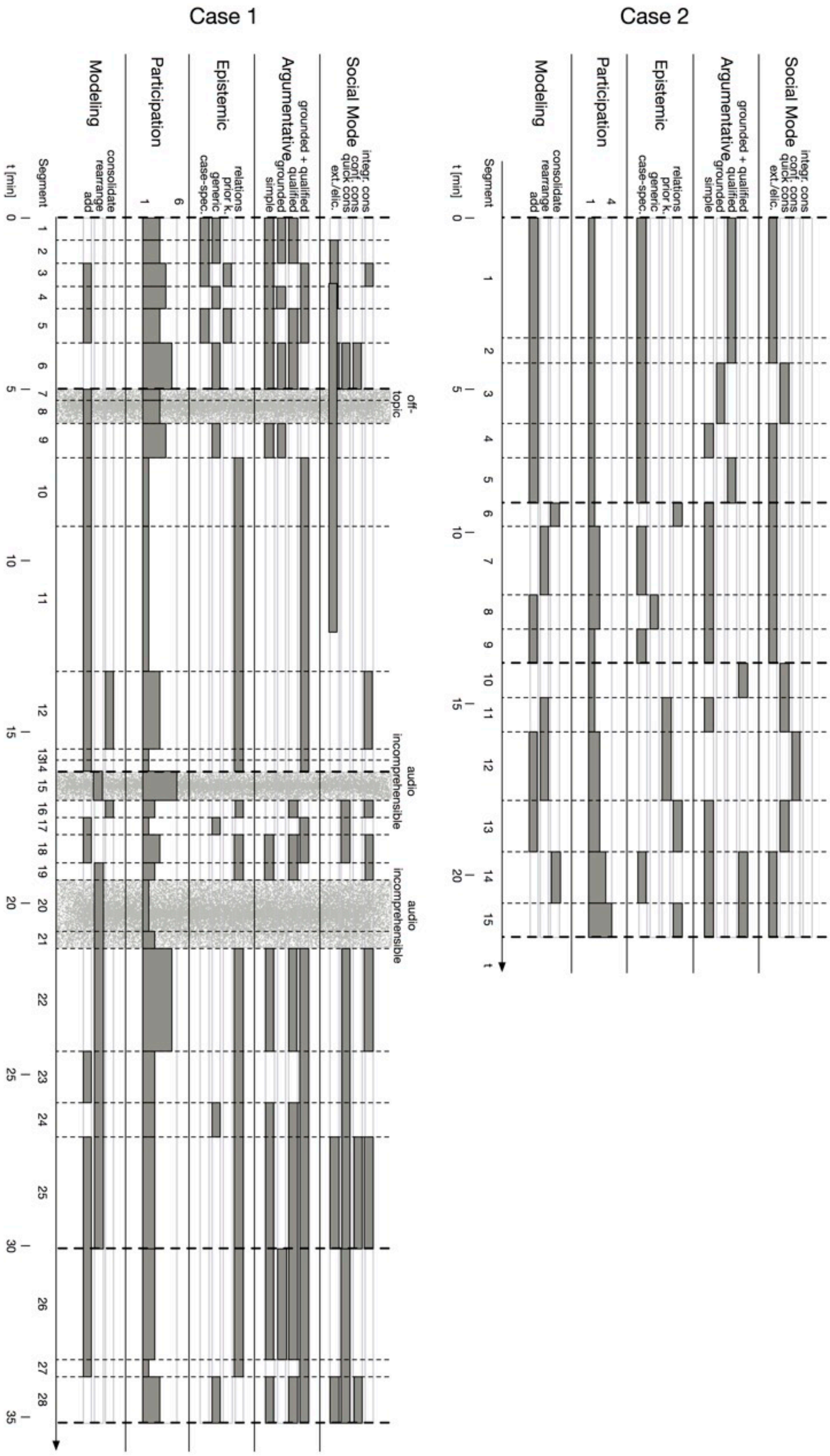

Figure 6.5: Interaction analysis for case 1 (left) and case 2 (right)

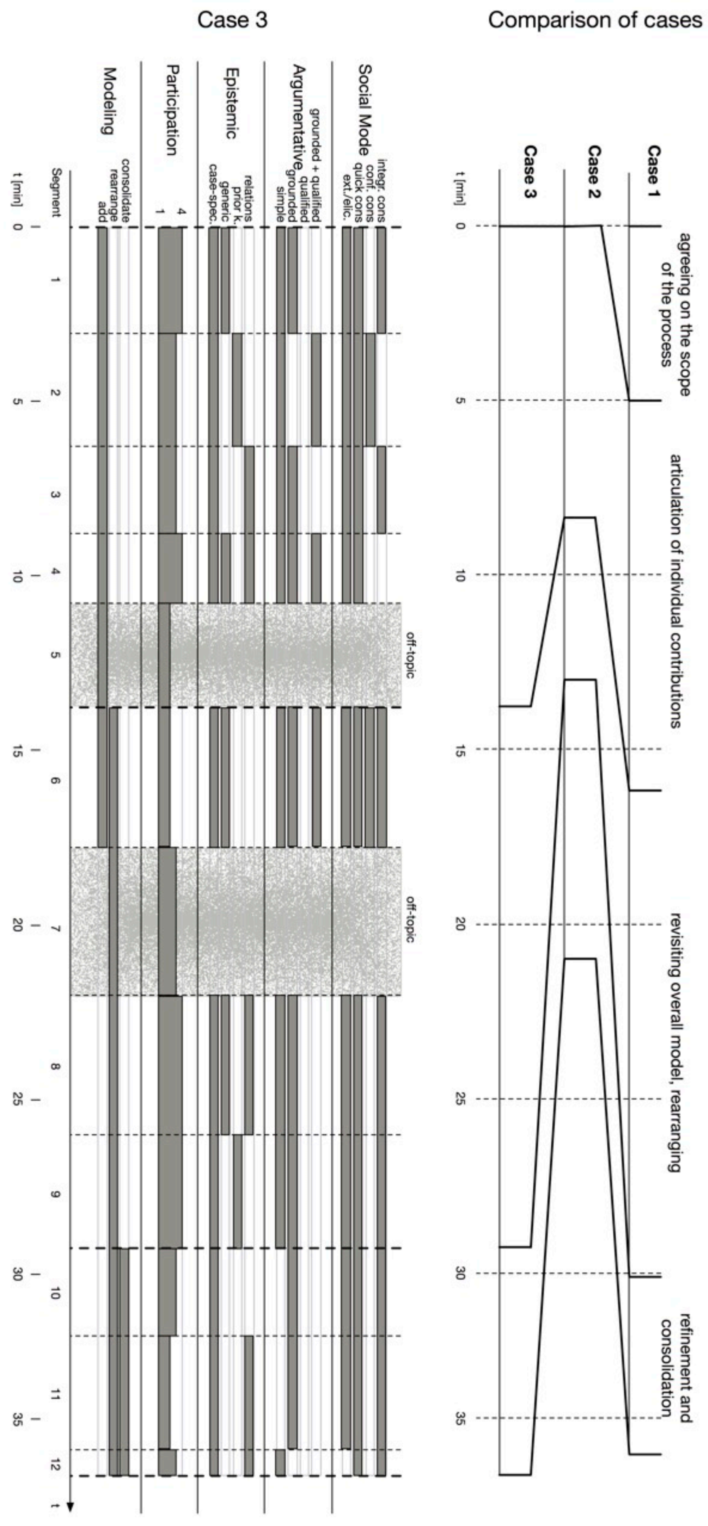

Figure 6.6: Interaction analysis for case 3 (left) and interaction macro-segments compared for all three cases (right)

The final phase was dedicated to consolidation and wrap-up activities. While all three cases differ in the pattern they show in terms of model manipulation (which generally declines), they all show an amount of argumentative and consensus-building activities in the field of relating concepts and model views with each other. The focus of interaction shifts away from manipulating the created model and towards finding a common understanding of the model.

6.4.2.3 Evaluation of perceived outcome and support

Evaluating the individual perception of workshop participants has been carried out using quantitative methods, while the other two parts of the evaluation rely on qualitative approaches. The discussion of the validity of the propositions in this case thus can benefit from reviewing the overall results summarizing the questionnaires from all workshops.

In addition to the case results, we therefore summarize the overall results from the 12 examined workshops in the following. In total, 174 questionnaires have been considered for the analysis. The sample size for the different construct varies, as not all participants provided answers to all items used to calculate the variables. All constructs have been tested for being significantly different from the scale's median value of 3 ($p < 0.05$). The values for all constructs significantly deviate from a normal distribution (Kolmogorov-Smirnov test for one sample, $p < 0.05$) and thus were tested using the Wilcoxon test (H0: median-value of construct x equals 3) and the Mann-Whitney-U-test (H0: median-value of construct x is equal for cases A and B). Table 6.3 summarizes the results for all constructs. For the overall and case-specific columns, cells that are marked with a gray background and italic font indicate a variable, for which the median value was significantly different from 3 with $p < 0.05$ (i.e., H0 had to be rejected), indicating significant agreement to the statement represented by the variable. For the case-comparison columns, cells that are marked with a gray background indicate a significant ($p < 0.05$) difference in the examined construct for the compared cases (i.e., H0 had to be rejected). The cases indicated in each cell designate those, which have been rated significantly lower (i.e. better – examined with one-sided Mann-Whitney-U-test).

The results of all constructs in the area of methodological support during the articulation process (Prefix *S*) are significantly lower than the median value of the scale. For the constructs indicating relevance and usefulness of the articulation process (Prefix *P*) and those referring to the perceived articulation outcomes (Prefix *O*), the overall picture is more heterogeneous. Construct *O-LearnCom*, referring to the perceived amount of learnings about communication in collaborative work processes in general, does not show significant results for either case. Only the overall result shows a significantly lower value than the median of the scale. Construct *O-LearnTop*, referring to the perceived amount of learnings about the articulated work process, shows values below the median of the scale, which are mostly significant. The values, however, are based on a relatively small number of statements when compared with the other variables, indicating that a large amount of participants were undecided in this respect.

Table 6.3: Results of ex-post questionnaire

Construct		Overall	Case 1	Case 2	Case 3	C1 - C2	C1 - C3	C2 - C3
Relevance of articulation process (P-Rel)	n	170	9	11	22			
	mean	2,76	3,06	2,32	2,25			
	std-dev	1,13	1,07	1,10	1,18			
Usefulness of articulation process (P-Use)	n	171	10	11	22			
	mean	2,12	2,30	2,50	1,84			C3
	std-dev	0,86	0,82	0,74	0,59			
Usefulness of workshop outcome (O-Use)	n	164	9	11	22			
	mean	2,70	3,06	1,98	2,63	C2	C3	C2
	std-dev	0,61	0,78	0,69	0,34			
Relevance of workshop outcome (O-Rel)	n	170	8	11	22			
	mean	2,09	3,08	2,33	1,55		C3	C3
	std-dev	0,88	1,22	0,75	0,47			
Learned about interaction (O-LearnCom)	n	155	9	11	22			
	mean	2,77	2,89	2,46	2,89			
	std-dev	0,61	0,74	0,85	0,51			
Learned about topic (O-LearnTop)	n	146	3	8	22			
	mean	1,84	1,33	2,00	1,23			C3
	std-dev	1,00	1,53	0,54	0,43			
Complexity of tasks during workshop (S-Comp)	n	169	11	11	22			
	mean	1,67	1,92	1,65	1,29		C3	C3
	std-dev	0,82	0,86	0,47	0,33			
Understanding of tasks during workshop (S-Underst)	n	174	11	11	22			
	mean	2,71	2,09	2,27	2,79		C1	C2
	std-dev	0,66	0,70	0,56	0,40			
Perceived stress during workshop (S-Stress)	n	168	10	10	22			
	mean	1,90	1,35	1,45	1,66			
	std-dev	1,13	0,34	0,69	0,89			
Ease of task implementation (S-Easy)	n	170	11	11	21			
	mean	2,19	1,94	2,15	2,14			
	std-dev	0,66	0,61	0,52	0,62			
Facilitation through workshop setting (S-Facil)	n	171	11	11	22			
	mean	2,15	1,77	2,09	1,91			
	std-dev	0,79	0,79	0,66	0,67			

When comparing the cases, some interesting relations can be identified on the level of constructs. In general, cases 1 and 2 show significant differences only for one construct, which is related to the usefulness of the workshop outcome. More significant differences can be identified in relation to case 3. The majority of differences can be found for constructs related to outcome (Prefix *O*) here.

The construct related to usefulness of the workshop outcome (*O-Use*) has been rated significantly more negatively for case 1 in comparison to both other cases. Relevance of the outcome (*O-Rel*) is rated significantly better for case 3 than for the other two cases. The complexity of the tasks to be completed during the workshop (*S-Comp*) has been rated to be significantly less demanding for case 3. The understanding of the tasks to be completed (*S-Underst*), however, was rated significantly better for cases 1 and 2. No significant differences were found in the constructs related to the workshop setting, including the structural support measures (*S-Facil, S-Stress, S-Easy*). Also, the perceived relevance of the articulation process (*P-Rel*) and the perceived learning about the importance of reflecting about interaction in operative work (*O-LearnCom*) did not show any significant differences across the cases. The findings about the topic of modeling (*O-LearnTop)* and the usefulness of the articulation process during the workshop (*P-Use*) was rated significantly better for case 3 than for case 2. Case 1 here did not show any significant differences for these constructs to either, case 2 or 3. These results will require further reflection in light of how cases the cases differ with respect to the amount and quality of facilitation and the perceivable added value of the workshops. These aspects will be discussed in the following section.

6.4.3 Discussion

The three presented cases have shown the application of the proposed methodology in different professional sectors, with different quality of facilitation and with a different amount of perceivable impact of the outcome for the participants. However, they had in common their application domain of reflective purposes in vocational training. This might limit the generalizability of the findings discussed below. Still, as all cases were conducted in a real world context, they are valid selections for the purpose of this study as outlined in the beginning of this section.

The following will present the evaluation results in three steps. First, we will review the evaluation results in light of the research proposition and the expected evaluation results identified in Section 6.4.1. Second, we review the observed differences among the cases and discuss them in the light of the different qualities of facilitation and perceivable outcome. Third, we give an account on the implications of these results for the overall objective of the present research.

6.4.3.1 Discussion of the Evaluation Proposition

If the research proposition is valid, the evaluation of the modeling process should have confirmed the following propositions about the workshop process: *(1) Participation*: *should show the involvement of multiple participants.* This has been confirmed in all three cases, since all participants actively contributed in each workshop. Whether interaction is sequential or simultaneous depends on the different identified phases during confrontative consolidation. (2) *Epistemic*: *mainly shows statements about the problem space. Statements about the conceptual space could be observable but are not necessarily to be expected.* In general, confrontative consolidation starts with problem-space specific statements, which gradually develop towards more generic statements over time. This claim thus can be confirmed. (3) *Argumentative claims*: *claims should be grounded and/or qualified whenever a conflict in EXCHANGE- or WHO-elements is discovered and resolved in the model during collaborative consolidation.* Argumentative claims are mostly grounded and/or qualified across all three cases when consensus building activities are carried out. Simple claims accompany the whole process, largely in the context of externalization and elicitation activities (i.e., when participants talk about their work without explicitly constraining their statements to a specific case). This claim thus can be confirmed. (4) *Social modes of co-construction*: *Externalization and elicitation is prevalent, when individuals contribute their views on the work process, potentially interrupted by elicitation intervention by others. Whenever conflicts are discovered, consensus-building activities are observable.* In general, this claim can be confirmed for all cases. Interestingly, interruptions of externalization activities hardly could have been observed (with the exception of case 3, where the structured modeling approach has hardly been adopted). Consensus building activities are largely only to be observed in later stages of confrontative articulation, when the externalized models were revisited. This might be attributable to the structured externalization process in cases 1 and 2, which guided the participants through the process of initially creating the common model and which hardly showed any fundamental difference in their perceptions.

In order to confirm the formulated proposition, the variables of the questionnaire prefixed with *P* (perceptions about the workshop process) and *O* (perceptions about the workshop outcome) should show a value that is significantly ($p<0.05$) better (i.e. lower) than the scale's median value of 3. Considering the overall results for all workshops that were carried out, this is the case for each variable. When reviewing the single cases, not all results are significantly better than the median value, and for some variables of case 1 they even exceed the median value. For case 1, these mixed results might be explainable with the lack of experience the participants had with their work process and consequently their problems of identifying potential added value of the workshop. Interestingly, the results for case 3, which hardly made use of any of the structural guidance measures provided in the methodology, are also consistently significantly lower than the median value. Ignorance of the structural guidance measures for modeling in case 3 thus led to less understanding of the modeling support measures, while the overall setting still was considered supportive. The perceived relevance and usefulness of the workshop still is significantly positive for case 3, as are the variables referring to the perceived support of the methodology (prefixed with *S*) and are similar to the results of cases 1 and 2. This can be interpreted as an indicator that multi-perspective articulation as the fundamental concept of CoMPArE has been recognized to be of value, but the guidance measures still support the understanding of the modeling process (as in cases 1 and 2). The proposition thus can be confirmed in light of the presented results.

6.4.3.2 Discussion of difference between cases

A closer look at the differences among the cases as identified in both, the quantitative study as well as the interaction analysis, allows to draw conclusions on how the proposed methodology should be deployed in practice. We thus in the following discuss these differences along the dimensions that distinguish the cases identified in Section 6.4.2.1.

The *professional background of the participants* did not seem to have any impact on the workshop process and outcome. All cases show similar interaction patterns and the questionnaire constructs do not show any differences that can be attributed to the process-oriented background of the participants in case 2 compared to the interaction-centric backgrounds in cases 1 and 3. The resulting models, which are not discussed in the present chapter, however, show different patterns of how participants represent their work. While in case 2, the model depicts a sequential flow of activities that are linked via acts of document-exchange, the models in cases 1 and 3 are more dynamic, showing simultaneous activities and acts of communication, which are not unambiguously anchored on tasks but on actors only. While these patterns are not surprising and in line with the nature of work in the respective domains, they need to be further examined in terms of whether the modeling notation or the structural guidance measures require modification to account for these different modeling strategies.

The *amount and quality of facilitation* was different in all three cases. We have reviewed facilitation with respect to the extent to which the structural and procedural guidelines proposed in the methodology were enforced. Case 1 here adopted a laizzer-faire approach, in which the facilitator pointed out the guidelines but did not enforce them, case 2 was facilitated strictly following the guidelines, and case 3 was carried out without any human facilitation. Interestingly, the facilitation of the collaboration through the workshop setting was not perceived significantly differently across the cases. However, the understanding of what the participants were expected to do was rated significantly better for cases 1 and 2, hinting at the importance of active human facilitation of the collaboration process. Still, the observed interaction patterns are similar across all cases, which could be attributed to the fact that the model consolidation scheme is sufficiently easy to be implemented without explicit guidance during the process. The fact that participants perceive the tasks significantly less complex in case 3 can be attributed to leaving aside the individual modeling step and consequently not having to adhere to any consolidation procedures.

The *perceivable added value of the workshop outcome for the participants* appears to have had impact on the perceived usefulness and relevance of the workshop. Despite it's rather unstructured nature, case 3 shows significantly better results for most constructs related to this aspect than the two other cases. We attribute this to the fact that participants were told that their results will have immediate impact on the future implementation of the real-world work process. Case 1, in which no potential impact was communicated to the participants, shows the worst results in this area. The perspective of producing impact on an organization level beyond the level of individual understanding appears to improve the perceived relevance and usefulness, as can be seen when comparing the results of cases 2 and 3.

Summarizing, the methodology appears to have positive effects even when not accompanied with explicit human facilitation. Still, the understandability of the procedures to be carried out and their appropriate implementation benefits from human facilitation following patterns of a "catalyzing engineer" (Hjalmarsson et al. 2015), such as guiding how to best use the provided modeling artefacts. The perceivable added value largely seems to be independent of the actual modeling process but driven by external factors such as the communicated further use of the workshop outcome.

6.4.3.3 Discussion of overall objective

The objective of the present work is to provide a methodology that offers structural and procedural guidance for conceptual modeling to support the collaborative of a shared understanding on collaborative work. This should be achieved by implementing the features identified in Section 6.2. Their implementation is described at the end of Section 6.3. We therefore discuss whether the overall objective can be considered met based on the empirical results regarding the implementation of the features.

F1, in which individual understanding is codified in separate models by each actor and consolidated in a separate step, and *F2*, in which divergent understandings among the involved actors are identified and explicitly made visible, have been implemented by structural guidance measures. The empirical results show that in the cases in which the structural guidance measures have been applied, the participants have a better understanding of what they are asked to do content-wise and feel that they gain added value from the application of the guidance measures. The implementations of F1 and F2 thus appear to contribute to the overall objective.

F3, in which the process of consolidation requires procedural guidance, has been realized by specifying consolidation guidelines to be provided to the participants by a facilitator. This has been the case in all three described cases. All cases expose similar interaction patterns throughout the consolidation process, independently of whether or not the structural guidance measures were applied. This is an indicator for successful implementation of F3 in light of the overall objective.

F4, in which the used modeling language must be adequate for the intended target group and appropriate for the aim of modeling, has been implemented by providing an actor-oriented, communication-centric modeling language with flexible semantics. The modeling results and results for the ex-post questionnaires in the three cases show that this language was largely adequate for the target group and also allowed to represent the relevant issues. Still, the participants were not able to apply a consistent understanding for all modeling elements throughout the whole session. This is not necessarily an issue for the primary aim of the method, for which the models only act in situ as mediating artifacts. However, if they should also be used for later referral, these inconsistencies could pose a challenge, as the exact semantics are not explicitly documented. Overall, F4 can be considered to be successfully implemented for the aims of the present work but show potential for improvement to be addressed in future iterations of the methodology.

Based on these results, the overall objective pursued in the present work can be considered reached. Whether or not a shared understanding actually was reached has not been addressed in the present chapter and should be the subject of future empirical research.

6.5 Conclusions

This chapter has introduced a methodology that enables organizational actors, who are not expert modelers, to construct collaboratively a shared understanding of their work processes. The collaborative construction process is supported by conceptual models, which act as artifacts to identify and make visible divergent views. The design of the methodology prioritizes guidance measures for using the models to create a shared understanding over semantic completeness of the resulting model. The methodology builds upon guidance measures, which are encoded in the structure of the proposed modeling language and its visual representation. Procedural guidance is provided by a facilitator. The views of the actors on their work processes are initially individually represented in models. These models are collaboratively consolidated to create a representation, on which all actors agree. During the process of consolidation, divergent views are identified and need to be resolved in order to create a common model.

The proposed methodology and its structural and procedural guidance measures have been validated by the multi-case study described in Section 6.4, which confirmed that the methodology meets the objectives. The major contributions of the present work consequently are, firstly, the empirical results that show that collaborative conceptual modeling is a suitable means for making visible different viewpoints on work processes and aligning them to develop a shared understanding. The second is the developed evaluation approach for analyzing the interaction process during modeling, which allows us to examine a collaborative modeling process with respect to its effects on the construction of a shared understanding among the involved actors. From a practical perspective, the main contribution is the described methodology, which facilitates the process of creating a shared understanding via structurally and procedurally guided conceptual modeling.

The present work has some *limitations*. First, the construct validity of the proposed empirical methodology has not been tested. The lack of a baseline for comparative evaluation with other similar approaches limits the validity of statements on the added value of the proposed approach. The combination of the quantitative and qualitative evaluations conducted in the case study, however, still shows that the objectives of the methodology fundamentally have been reached and gives valuable insights for potential areas of improvement. Following a design science approach, this provides the foundation for the next iteration of the designed artifacts. Second, the cases have all been carried out in an educational setting and thus might be of limited generalizability for arbitrary collaborative work settings. The target group and the selected work process in all cases, however, have been in the general scope of the empirical study (real-world collaborative work reflected upon by actors without experiences in conceptual modeling). Thus, the results allow conclusions to be drawn with respect to the formulated research proposition. Third, the resolution of divergent views during consolidation has not yet been sufficiently researched in terms of methodological guidance. While the descriptive analysis of the identifiable behavior during consolidation provides a starting point for choosing appropriate interventions, further research should enable improvement of the methodology.

In *future work*, further experimental and practical validation of the proposed empirical methodology for analyzing the interaction process during modeling is planned. It will be examined regarding its use as an analytical tool for explaining knowledge-intense collaborative modeling activities. The proposed modeling methodology will be deployed in more diverse organizational settings and its effects will be evaluated in more detail. This will require evaluation setups that go beyond analyzing the process of modeling and its immediate outcomes, and also consider the effects on the implementation of the collaborative work process itself. The findings from these evaluations will further refine both the methodology and the guidance measures. Future iterations of the design will focus on improving the guidance measures and back them with technical support for scaffolding the articulation and consolidation process, e.g., based on the concepts introduced by Land & Zembal-Saul (2003), Dennen (2004), and Sandkuhl & Lillehagen (2008).

6.6 Appendix A – Evaluation instrument

Construct	No	Item definition	Items drawing on
Relevance of articulation process	P-Rel1	During group discussion, I felt that I could contribute my view on the work process	Sedera et al. (2002)
	P-Rel2	My understanding of the topic changed during the workshop	
Usefulness of articulation process	P-Use1	During group discussion, I recognized areas of improvement in the work process	Sedera et al. (2002)
	P-Use2	During group discussion, misunderstandings regarding cooperation in the work process became apparent	
Usefulness of workshop outcome	O-Use1	The workshop was not useful for me[a]	Gemino and Wand (2004)
	O-Use2	I am confident to use the knowledge gained form the workshop in my future work practice	
	O-Use3	Overall, I perceived the workshop to be very useful	
Relevance of workshop outcome	O-Rel1	The workshop was relevant to me	Recker et al. (2013), Gemino and Wand (2004)
	O-Rel2	The workshop addressed skills and knowledge relevant for my future needs	

Construct	No	Item definition	Items drawing on
	O-Rel3	I am going to tell other people about what I learned in this workshop	
Learned about interaction	O-LearnCom1	The workshop did not influence my thinking about interaction in work processes[a]	Krogstie et al. (2006)
	O-LearnCom2	The workshop made me think about communication issues	
Learned about topic	O-LearnTop1	The workshop expanded my thinking about the topic	(Krogstie et al. 2006)
Complexity of tasks during workshop	S-Comp1	For my level of experience, the workshop was too advanced[a]	Gemino and Wand (2004), Sedera et al. (2002)
	S-Comp2	The workshop was suitable for my level of experience	
Understanding of tasks during workshop	S-Underst1	The workshop objectives were clear to me	Gemino and Wand (2004)
	S-Underst2	The workshop was not logically organized[a]	
Perceived stress during workshop	S-Stress1	There was adequate time for interaction	Gemino and Wand (2004)
	S-Stress2	The assignments and activities were reasonable and appropriate in the time allowed	
Ease of task implementation	S-Easy1	I felt motivated to make a contribution to the group discussions	Recker et al. (2013)
	S-Easy2	In the course of discussion my group came easily to a common understanding	
	S-Easy3	During group discussion, it was not easy to come to a consensus[a]	
Facilitation through workshop setting	S-Facil1	The setting of the workshop facilitated discussion among participants	Kolfschoten and Vreede (2009)
	S-Facil2	The workshop activities stimulated my learning	

[a] Item with inverted scale

7 Recognition of paper-based conceptual models captured under uncontrolled conditions[1]

7.1 Introduction

The collaborative development of conceptual models (Davies et al. 2006) is a crucial activity in the area of concept mapping (Stoyanova & Kommers 2002; Gao et al. 2007) or user-centered requirements engineering (Barjis et al. 2009; Mullery 1979; Rittgen 2009b). Both fields of research aim at creating a digital representation of these models to enable documentation and further processing (Davies et al. 2006; Novak 1995). Historically, collaborative conceptual modeling has been carried out with paper-based means (Dann 1992). Paper-based modeling provides the benefit of representing a model in the form initially conceived as a mental concept. Due to its efficacy in externalizing concepts, paper-based sketching is used in development practice for externalizing designs. Moreover, it allows the gradual development of more sophisticated forms of conceptual knowledge (Farrugia et al. 2014). Paper-based models, however, need to be transformed to digital representations in a separate step. The process of manual transformation requires considerable effort to carry out and disrupts model processing, and thus should be avoided (Wüest et al. 2013). Research in the last years has proposed to create fully digital environments that support the collaborative modeling process from the very beginning (Rittgen 2009a; Herrmann & Nolte 2014; Santoro et al. 2000; Mendling et al. 2011). Such approaches have been shown to have deficiencies with respect to the social dimension of the collaboration process during modeling (Do-Lenh et al. 2009; Hornecker 2005), particularly in terms of equal access to contribute to the model and facilitating appropriation of the represented concepts (Wüest et al. 2015) and in terms of mutual awareness of modelers' activities (Davies et al. 2006). With the advent of interactive surfaces, a trend back to co-located direct collaboration based on

[1] This chapter is identical in terms of content to the accepted final version of the article „Oppl, S., Stary, C., & Vogl, S. (2016). Recognition of paper-based conceptual models captured under uncontrolled conditions. IEEE Transactions on Human-Machine-Systems, in press. http://10.1109/THMS.2016.2611943“. It has been modified to provide consecutive numbering of sections and figures throughout this thesis.

a digital representation of the model can be recognized (Oppl & Stary 2009; Dillenbourg & C. Shen 2009; Kay et al. 2010; Baraldi et al. 2006). These approaches have solved the prevailing problems of digitally capturing a conceptual model while maintaining a social setup that appropriately supports the collaborative processes during modeling (Do-Lenh et al. 2009; Oppl & Stary 2014; Hornecker 2001; Lucchi et al. 2010). The required infrastructure, however, is complex, expensive, and usually can only be relocated with high effort (Müller-Tomfelde & Fjeld 2012; Soares et al. 2013). The ability to bring the modeling environment to the modeler is especially important in organizational settings, where situated elicitation supports capturing a more rich set of information from domain experts (Nunes et al. 2009). Tablet computers are not an appropriate solution in this context, because they are single user devices and lack the embodiment of representation necessary to facilitate the collaboration dimension during modeling (Hornecker 2005; Bang & Timpka 2007). A variety of approaches has tried to tackle the challenge of capturing digital representations of manually created conceptual models via image recognition (e.g., (Jiang et al. 2011; Forbus & Usher 2002; Stapleton et al. 2015; Ghorbel et al. 2015)). They rely on paper-based modeling techniques and extract digital model representations from images taken of the paper based models. The problem to be solved here is a subclass of sketch recognition, which has been a subject of research as early as in the 1970s (Negroponte 1973). Since then, numerous approaches to improve recognition speed and reduce recognition errors have been proposed. The problem of sketch recognition thus can largely be considered as solved when performed on images captured under controlled conditions. Jiang et al. (2011) describe a system to derive digital representations from sketched conceptual models and give an overview about the historic development of the field.

The current chapter thus does not set out to advance the state of the art in sketch recognition itself, but proposes a system that is embedded in an ensemble of instruments supporting collaborative modeling processes. Its novelty is in the integration of the described instruments to a complete, self-contained system. The system focuses on enabling users to capture their sketched models without constraining them to controlled capturing settings. Extracting features from images captured under uncontrolled conditions has hardly been a topic in the area of sketch recognition, but rather has only recently been addressed in face recognition (Adamo et al. 2013; Wechsler 2014; De Marsico et al. 2013) and optical character recognition (OCR) (Bissacco et al. 2013).

The aim of this was to integrate paper-based modeling as seamlessly as possible in a modeling workflow comprising different computer-supported collaborative conceptual modeling tools. This is in line with current research in the field of requirements engineering (e.g., (Wüest et al. 2015; Vogel et al. 2014)). This research, however, does not address the recognition of models from pictures captured under uncontrolled conditions, but rather focuses on semantic interpretation of sketched models.

The present research is to be motivated from a design science perspective (Hevner et al. 2004). Our earlier research has focused on supporting collaborative modeling on interactive tangible tabletop surfaces (e.g., (Oppl & Stary 2014)). Experiences from evaluation in real-world settings have made evident that users demand to reduce the technical (in terms of required infrastructure) and cognitive effort (in terms of needing to learn the handling and constraints of a new tool) to contribute to collaborative modeling processes. From a practitioner's perspective, the contribution of the present research is thus an IT artifact that allows for situated capturing of sketched conceptual models by users themselves, which can be aligned easily with more sophisticated IT-based modeling tools. Of scientific originality thereby is the introduction of a recognition system that enables the extraction of paper-based model sketches from images captured under uncontrolled conditions.

The proposed capturing system sets out to relax the constraints on model extraction from images of paper-based models. It should tolerate shortcomings in both, image capturing (e.g., superficial content, skew) and the drawings themselves (e.g., bad pen quality, suboptimal drawing accuracy) in order to allow situated modeling and capturing by users (Jiang et al. 2011). At the same time, it must be easy to use and inexpensive to deploy in users' workplaces and should not rely on dedicated technology (Wei et al. 2015). It should not be limited to specific modeling languages and should produce generic model representations that can be directly propagated to other IT tools for further processing (Wüest et al. 2015).

The remainder of this chapter is structured as follows: in the next section, we describe our context of use and derive the requirements to be fulfilled by a set of tools for the recognition of paper-based conceptual models. In Section 7.3, we present the current state of the art of model extraction from paper-based models and identify the contribution of the present work. Section 7.4 reports on the implementation of the current prototype of the toolset. Section 7.5 reviews the current performance and reveals the limitations of these tools from an application perspective. We proceed with a field study, in which we report on the practical use of the toolset in an organizational development setting. The paper closes with an account on further directions of research.

7.2 Requirements on model recognition for end user-driven conceptual modeling in knowledge-intense organizational environments

The user-centric design of the envisioned system needs to take into account its context of use and the socio-technical system environment it is embedded in. We therefore briefly describe the overall system that has been designed to support collaborative modeling processes in organizational settings to facilitate reflection and learning processes. We then derive requirements on the system, taking into account the constraints imposed by the envisioned context of use.

7.2.1 Socio-technical System Context

The context of the system described here has been developed based on the *Knowledge Life-cycle* (KLC) (Firestone & McElroy 2005), which describes learning processes in organizations. The KLC fundamentally distinguishes between a "business processing environment" (lower part of Figure 7.1), in which operative work is carried out, and a "knowledge processing environment" (upper part of Figure 7.1), in which new knowledge about organizational work is developed, assessed and distributed. Work in organizations is based on the "distributed organizational knowledge base" (DOKB, lower right corner of Figure 7.1), which comprises the codified knowledge of an organization as well as the subjective knowledge of its members. Whenever work leads to results that have not been expected based on the knowledge available in the DOKB, a mismatch is diagnosed that leads to compensation activities (lower center region of Figure 7.1). If a mismatch cannot be compensated ad hoc, the knowledge processing environment is entered (top left corner of Figure 7.1). In this process, a "problem claim" is explicitly formulated. Based on the "problem claim", "knowledge claims" — i.e., potential solutions to the problem—are developed. They undergo a validation process, which can lead to refusal of the knowledge claim or trigger the need for revision (upper center region of Figure 7.1). If a knowledge claim "survives" validation, it is distributed across the organization via different means of sharing (top right corner of Figure 7.1). In this way, it is integrated in the DOKB and becomes part of the foundation for future organizational work. Figure 7.1 also shows the main instruments that have been developed for supporting the implementation of the KLC. Those instruments are briefly described in more detail below to enable the identification of requirements on the system described in the present chapter.

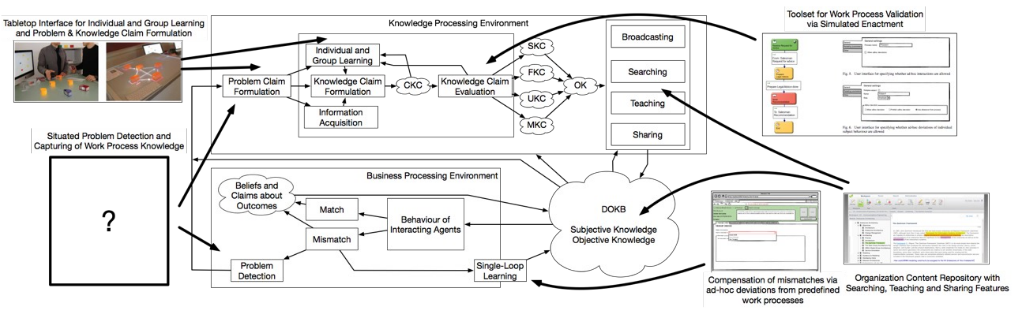

Figure 7.1: Overall system context, based on Knowledge Lifecycle

Our research has focused on support for activities in the knowledge processing environment so far, with tools supporting the collaborative development of a shared understanding about a work context (Oppl & Stary 2014), negotiation processes for setting up or revising work procedures (Oppl 2015), validation of proposed work processes (Schiffner et al. 2014), and sharing (Neubauer et al. 2013) and contextualizing (Fürlinger et al. 2004) the developed artifacts in an organization. All of them support the operationalization of the knowledge processing environment depicted in the upper part of Figure 7.1. Further instruments have been developed to support compensation activities for mismatches occurring in the business processing environment depicted in the lower part of Figure 7.1 (Schiffner et al. 2014; Kannengiesser & Oppl 2015). The remaining gap is to identify problem claims directly in a work situation. Bridging this gap would enable organizational members to articulate their view on the occurred mismatches. It could facilitate the transition from the business processing environment to the knowledge processing environment and allow starting knowledge production by providing context from the actual work situation.

The instruments developed for supporting the knowledge processing environment (Oppl & Stary 2009; Wachholder & Oppl 2012) have been shown to fulfill their design goals (Oppl & Stary 2014), but require dedicated technical infrastructure. This prevents their deployment in operative work settings as well as operation without support staff trained to solve technical issues. The design goals for the system to be developed for bridging the gap indicated in the lower left corner of Figure 7.1 can thus be formulated, based on the requirements from the intended context of use, as follows:

1. The system must not require technical infrastructure beyond mundane devices, such as digital cameras.
2. The system has to allow operation by non-technical staff and consequently must not require detailed technical knowledge for setup and use.
3. The system has to be technically compatible with the other instruments deployed in the overall ensemble in the KLC. In particular, the data representation for models has to be identical, and interfaces for interoperability have to be provided.
4. The system should enable users to produce identical outcome in terms of created models and modeling documentation as the other deployed modeling tools. In particular, it has to enable to build diagrammatical conceptual models with different types of nodes that can be linked via directed or undirected connections.

7.2.2 Requirements on Implementation

In this section, we describe how the abstract requirements described above should be operatively considered in the course of implementation, based on the existing set of tools.

The tabletop interface used for collaboratively articulating and reflecting on work-related knowledge has been implemented with optical recognition of passive modeling elements (Oppl & Stary 2009). In order to be able to re-use the existing technology stack for model processing and in the light of the first requirement made above, the design decision has been made to use paper-based models as replacement for the tabletop system, which should be extracted by optical recognition from pictures captured by users. The elements representing model concepts should remain tangible for the positive effects on collaboration caused by concept embodiment (Hornecker 2005; Oppl & Stary 2014). Optical capturing should not require any specialized capturing equipment. Consequently, the system should accept digital photos taken by traditional digital cameras or smartphones. The photos should be provided to the system via a web interface. In addition, uploading via a smartphone app should be enabled.

Requirement 2 operationally needs the model recognition system to not make any assumptions about the qualities of the provided picture aside from the need that the model needs to be captured completely and the image resolution has to be sufficient to appropriately extract the model content. More specifically, the system has to be able to extract model information from images with superficial image content, arbitrary orientation and skew. The system needs to tolerate the fact that users take pictures of their models blindly (because they are holding the camera over their heads) or with significant skew (because they have to step back in order to capture the whole model). Pictures with distortions caused by wide-angular lens of traditional smartphones must also be accounted for.

Requirements 3 and 4 should be accounted for by using the data format specified for model exchange in the overall system environment, which has been adopted by all tools that have been involved so far. This also allows users to re-use already existing interfaces to external tools, such as the export to the concept mapping toolset CMap-Tools (Canas et al. 2004).

7.3 State of the art in recognition of paper-based conceptual models and modeling

The challenges involved with creating digital representations of paper-based conceptual models were recognized as early as in the 1970s (Negroponte 1973). Operable solutions were enabled by increasing the processing power of computer systems and improved capturing devices (digital cameras), which were introduced in the 1990s (e.g., (Hwang & Ullman 1990)). Still, limitations remain in existence from a user-centric perspective (Jonson 2005), as most proposed approaches for recognition of sketched conceptual models rely on controlled capturing settings or assume the pre-existence of a digital drawing (e.g., created on tablets).

In the following analysis of the state of the art, we focus on model extraction from a digital representation of a drawing and on capturing pen-and-paper based models for further digital processing. Particular focus is placed on the feasibility of operation by end users under uncontrolled conditions.

7.3.1 Interpretation of Sketched Models

Hammond & R. Davis (2006) introduce a system for sketch recognition of UML-diagrams. It is not paper-based, but it supports input via tablet devices. Multi-stroke objects are recognized by their geometrical properties on several layers, and convey users' natural drawing, comparable to paper. The users receive visual feedback by the system while drawing. Sezgin & R. Davis (2005) also consider sketching as an interactive process which allowed them to ground recognizing sketches on Hidden Markov Models. Their user study revealed that in certain domains people have preferred ways of drawing objects. They were able to support people through recognizing regularities by consistent ordering of strokes without restricting the users to sketch in a certain way.

Stapleton et al. (2015) focus on bi-directional conversion of sketched and digitally created diagrams to facilitate an interactive, mixed-modal editing process. They illustrate their approach by applying it to Euler diagrams. Drawings are created with digital pen input. Their results show that a modeling process benefits from combinations of sketching and digital model manipulation, as both satisfy different user requirements in the course of model creation and manipulation. Similar results are presented by Vogel et al. (2014) for domain-specific modeling in software development.

The system proposed by Wüest et al. (2015) pursues similar objectives as the present research. They focus on facilitating collaborative sketching for requirements elicitation. Their approach follows a distributed collaboration model using multiple tablet computers for sketching. In their study, they found that—while the evolution of a common understanding of the model semantics is facilitated—the system lacks awareness features to communicate what other users are doing. This is an issue introduced by the use single-user devices for model sketching. Co-located, paper-based settings as deployed in the system proposed here do not suffer from this limitation.

7.3.2 Digitizing Paper-Based Models

Hwang & Ullman (1990) have proposed an approach for capturing sketched models as early as 1990. They have followed a domain-specific approach, focusing on recognizing CAD drawings. Due to the technical constraints of that time, capturing was assumed to happen under controlled settings, and focus was placed on algorithmic solutions for drawing recognition.

Jiang et al. (2011) aim to meet objectives similar to our work, as they focus on the extraction of concept maps from paper-based drawings. In their work, they combine dynamic programming and graph partitioning. Their algorithm can extract node blocks and link blocks of a sketched concept map by recognizing the text content of each concept node, and generating a concept map structure by relating concepts and links. Their results still need to be validated for uncontrolled capturing settings.

Ghorbel et al. (2015) present a system to create digital representations of handwritten architectural plans captured by end users with mobile devices. While their use case is not located in the area of conceptual modeling, they tackle the need for ex-post verification of recognition results by interactively involving users in the recognition process and let them intervene in case of structural or symbolic ambiguity of the model extracted from the captured image. As such, they were the first to explicitly address issues introduced by capturing under uncontrolled conditions. Their results from experimental validation show that it is feasible to provide meaningful recognition candidates for interactive verification. The approach currently lacks evidence of its applicability in real-world settings because empirical studies have yet to be performed.

7.3.3 Summary

Although current research already tackles the application scenario addressed in this chapter, several requirements according to the objective of our work have hardly been addressed explicitly and have not been examined in combination: (1) low cost or mundane devices are not explicitly addressed; (2) the level of expertise required for capturing is assumed to be available in most of the studies. Depending on the expected digital literacy of 'average' users, (3) tool chaining for embedding model capturing in larger frameworks such as the KLC has not been explicitly addressed, as it has not been a dedicated objective or research. While semantic, social, and pragmatic issues have been addressed with respect to user-centeredness, developers of stakeholder-oriented modeling support still need to integrate these findings, in order to ensure identical outcomes in terms of created models and modeling documentation when providing a chain of modeling and recognition tools. Technology-wise, related work does hardly address the challenges that come with capturing of model information under uncontrolled settings. Existing results (Jiang et al. 2011; Kara & Stahovich 2007), however, point at the difficulty of distinguishing nodes from connections in fully hand-drawn conceptual models. It thus can be useful for capturing under uncontrolled settings to adopt approaches used in augmented reality (Koch et al. 2014) and interactive tabletop interaction (Do-Lenh et al. 2009), where relevant elements are identified using clearly recognizable visual markers.

7.4 Implementation

In this section, we report on the current implementation of the toolset based on the requirements identified above. We start with an overview about the workflow of model recognition and then describe the tool support for the different steps. The different modules of tool support are indicated in Figure 7.2. Figure 7.2 also gives an overview about the (intermediate) result sets produced by the modules, which are further elaborated on in Section 7.4.4.

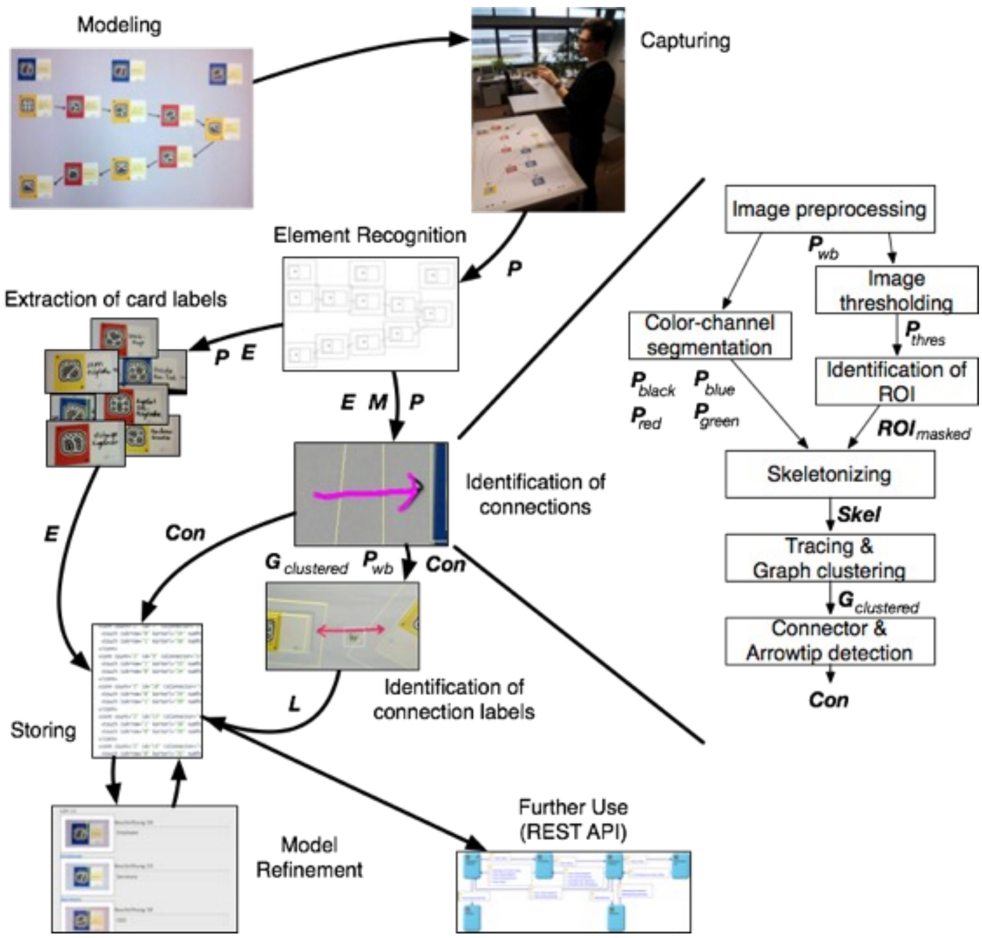

Figure 7.2: Overall workflow for recognition of paper-based models (italic designators refer to (intermediate) result sets as described in Section 7.4.4)

7.4.1 Overall Workflow

The process of model digitization already starts during modeling. The proposed toolset needs to deal with an arbitrary set of modeling languages elements, which are not constrained in shape or size. In order to meet this requirement, the elements bear unique visual markers to allow for reliable recognition.

Once the model is created, digitization starts with taking pictures of the model. Pictures do not need to be taken from a particular angle. It is possible to have several pictures, each showing only a part or details of the model. The pictures can be taken with a standard digital camera and subsequently uploaded to the recognition engine via a web platform. As an alternative, a smartphone app can be used to directly upload the pictures.

The recognition engine processes the pictures in a multistep procedure, which is described in more detail below. The first step is the identification of modeling the elements. Starting from the set of identified elements, the connections are identified in the next step. Finally, the recognition engine searches for labels of elements and connections, and extracts them for future reference. The result is displayed in a web platform and can be interactively refined there. This includes adding textual representations of the extracted labels. The final result is encoded as a XML file replicating the conceptual model structure and the visual layout.

Further processing can be performed with various tools. This includes model visualization, model editors, or post-processing software that interprets the results according to their conceptual or visual structure.

7.4.2 Modeling

Following the requirements, conceptual models can be created in any form, with any notation, and with any number of elements. The recognition engine also does not constrain modeling to a particular modeling surface, as long as it provides a sufficiently light-toned background for the modeling elements and connections sketched among them. As neither shape nor color of the modeling elements is constrained, their identification relies on the availability of a visual marker. Currently, ReacTIVision (Kaltenbrunner & Bencina 2007) is used as a marker recognition engine for its stability, robustness, and appropriate data output. The physical size of the markers needs to be identical and known to the system in order to appropriately scale the extracted model. ReacTIVision was adapted to work with single images stored in a folder and output its result as a XML file. Drawing connections is supported between an arbitrary number of elements, i.e., connections can be forked to connect more than two elements. Intersecting connections of the same color consequently cannot be recognized—they need to be of different colors to be recognized reliably. Connections need to start and end nearby a modeling element to be recognized. Labels of elements need to be written in a dedicated area of the modeling card. Labels of connections have to be placed nearby somewhere along the connection line.

7.4.3 Capturing

Model extraction requires one or several pictures of the paper-based model. One design goal of the developed toolset was to put as little constraints as possible on the pictures used for model extraction in terms of camera parameters, perspective, lighting, and number of contained model elements. One obvious constraint is the resolution of the digital image, which needs to allow for both the identification of visual markers and tracing of the connections. When multiple images are taken, a single model overview picture is required in the current implementation of the recognition engine to identify the positions of the model parts captured in the more detailed images. Matching of the model parts is performed on basis of the identified model elements. Consequently, the current constraining factor of model size is that all model elements need to be recognizable in the overview picture.

Following the requirement of not assuming the availability of any special hardware infrastructure, pictures can be taken with any digital camera and provided to the recognition engine via a web-based upload interface. The future envisioned standard gateway, however, is a smartphone app, which would also allow interactively providing feedback about recognition results to the user. The current prototype of this app allows capturing pictures and directly providing them to the recognition engine without the need to manually upload them.

7.4.4 Model Extraction

Model extraction is carried out by a set of instruments that implement the steps outlined in Figure 7.2. The entire collection is referred to in the following as *MoDig engine* (MoDig is used as an abbreviation of "model digitizer" here). Extraction is described here for single-picture models. Algorithmic differences for multiple pictures are described further below.

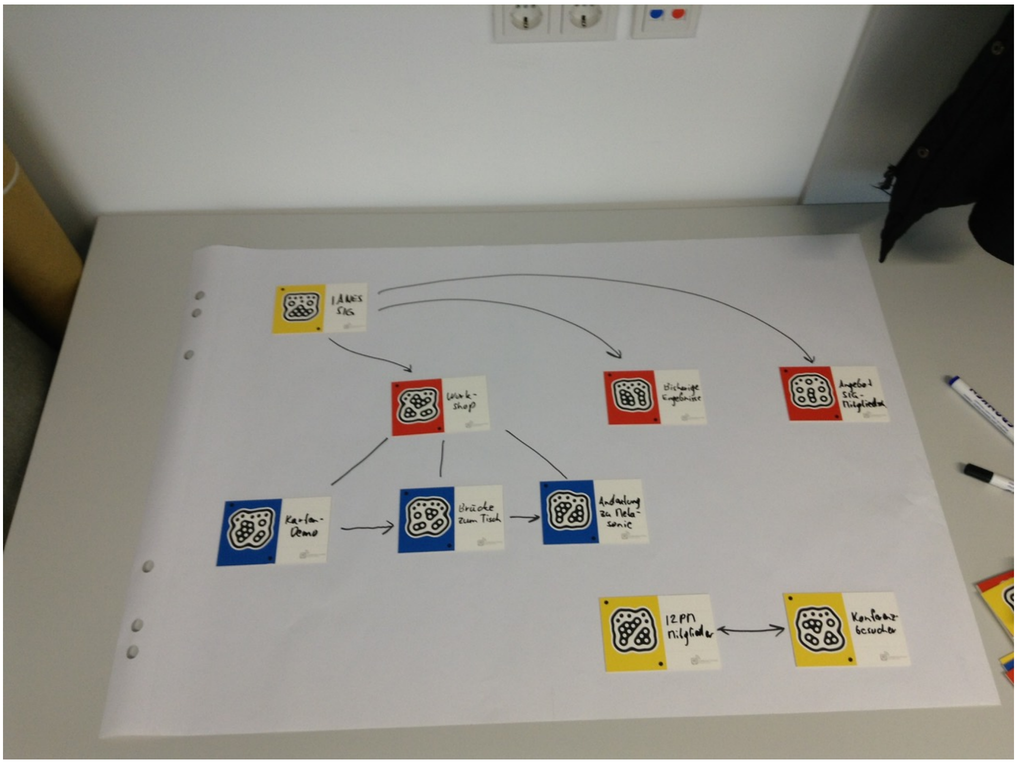

Figure 7.3: Sample picture used for illustration of recognition steps

For illustration purposes, the model depicted in Figure 7.3 is used as an example in the following sections. It has been created to visualize the planned activities to be carried out within a workshop at a scientific conference. The picture has been taken with a smartphone camera by a user standing in front of the table, on which the flipchart used as a modeling surface was placed.

The picture comprises superficial parts in its border regions, most notably the office artifacts on the left- and right-hand sides as well as the power outlets at the upper border. In the following formalization, the pictures is described as a set of pixels $P = [p_1, \ldots, p_n]$ with $p_i = (x_i, y_i, r_i, g_i, b_i)$, where (x_i, y_i) are the coordinates and (r_i, g_i, b_i) are the R/G/B values.

7.4.4.1 Element Recognition

Element recognition is performed by providing the source picture to the ReacTIVision engine, which identifies markers and outputs their position and rotation. More formally, this step produces a set $M = [m_1, \ldots, m_n]$, with $m_i = (id_i, x_i, y_i, rot_i, size_i)$ where id_i is the unique identifier of the marker, (x_i, y_i) indicates the coordinates of the center point of the marker in the 2D plane, rot_i is the rotation of the marker in *rad* related to the vertical axis of the picture, and $size_i$ is the length of the marker's diagonal (top left to bottom right).

Based on this information, the MoDig engine determines the size of the element by scanning for its border through identifying the colored rectangular region around it. It produces a set $E = [e_1, \ldots, e_i]$, with $e_i = (id_i, x1_i, y1_i, x2_i, y2_i)$.

The points $(x1_i, y1_i, x2_i, y2_i)$ determine the rectangular bounding box of the element. The extraction of card labels is based on this information. For each e_i, an rectangular image region is extracted. Its dimension is 1.5× the dimensions of the element's bounding box to provide the local context of the element. This supports later re-contextualization by the users. The image is rotated by $-rot_i$ and saved as a jpeg image element_{id_i}.jpg (cf. Figure 7.4).

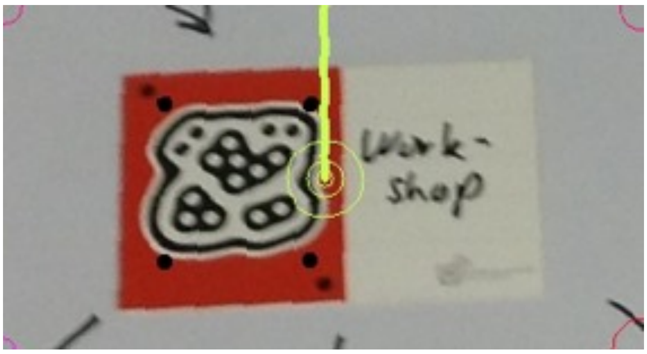

Figure 7.4: Extracted model element

Analog to the ReacTIVision engine, the system can deploy a second marker extraction engine that detects QR Codes. The output is a similar set of markers that can be processed identically while enabling users to link to marker information via smartphone apps during modeling.

7.4.4.2 Identification of Connections

Overview

Identifying connections between elements requires processing the source image in multiple steps. In general, the approach taken here first identifies a polygonal region of interest $ROI = [p_{1_{roi}}, \dots, p_{n_{roi}}]$ with $p_{i_{roi}}$ being the pixels selected as the polygon's vertices. The ROI designates the area, in which connections can be expected. It then skeletonizes the content contained in the ROI and searches for graphs $G = [g_1, \dots, g_n]$, with $g_i = [s_{i_1}, \dots, s_{i_n}]$, where s_{i_a} designate the line segments identified by the tracing algorithm to belong to the graph. It finally examines the identified graphs in regard to the likelihood of being an intentionally drawn connection. The result is a set $Con = [con_1, \dots, con_n]$ with $con_i = (m_{i_{start}}, m_{i_{end}}, dir_i, g_i)$, where $m_{i_{start}}$ and $m_{i_{end}}$ are the markers of the start and end elements, dir_i contains information on whether the connection is directed, and g_i refers to the graph the connection consists of.

Image Preprocessing

The aim of this step is to make potentially relevant "foreground" pixels better distinguishable from "background" pixels. In addition, color channels should be clearly separable in order to reliably detect differently colored connections. In the preprocessing step, the image is white-balanced (following a white patch approach (Lam & Fung 2008), as we assume that the modeling surface is light-toned) by identifying the dominant color tone of the brightest 10% pixels through averaging their RGB values, thus producing r_{white}, g_{white}, and b_{white}. The pixels of the white-balanced picture P_{wb} are then calculated as follows for compensating varying lighting conditions:

$$p_{i_{wb}} = \left(\frac{r_i}{r_{white}}, \frac{g_i}{g_{white}}, \frac{b_i}{b_{white}}\right)$$

The result of preprocessing is shown in Figure 7.5 (left) for the sample image.

Image thresholding and Identification of ROI

The next two steps identify the region of interest ROI, in which connections can potentially be expected. As the source image P not necessarily only contains the modeling surface, image parts with other contents need to be excluded from the ROI.

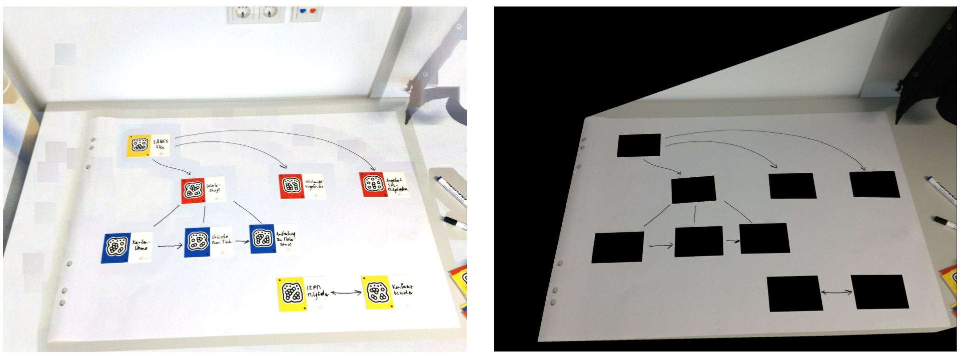

Figure 7.5: Left: result of preprocessing, right: masked region of interest

The ROI is identified by applying an adaptive threshold (similar to Otsu's method (Otsu 1975)) to a grayscale version of P_{wb} and a morphological closing with a filter kernel matching the biggest marker size to remove artifacts, e.g., caused by sketches. In the resulting binary image P_{thres}, the convex hull of the biggest blob defines the $ROI = [p_{1_{roi}}, \dots, p_{n_{roi}}]$ with $p_{i_{roi}} = (x_{i_{roi}}, y_{i_{roi}})$, where the polygon is described by the segments connecting $p_{i_{roi}}$ with $p_{i+1_{roi}}$, where $i = [1, \dots, n[$. For further processing steps, the modeling elements are not part of the area of interest and can also be excluded. The region to be processed therefore is $ROI_{masked} = ROI \backslash E$. Figure 7.5 (right) shows an overlay of the ROI_{masked} with the original image. Black regions are excluded from further processing. In order to identify line drawing such as text and connections, the pixel data needs to be condensed into a higher-level abstraction, which is performed in the next steps.

Color-channel segmentation

The input to the skeletonizing algorithm is a binarized image representing pixels that potentially belong to a sketched structure ("foreground"). One requirement has been to allow for different pen colors to draw connections. To allow for color segmentation, we produce a normalized version of the picture $P_{normalized}$ by calculating

$$p_{i_{normalized}} = \left(\frac{r_{i_{wb}}}{r_{i_{wb}} + g_{i_{wb}} + b_{i_{wb}}}, \frac{g_{i_{wb}}}{r_{i_{wb}} + g_{i_{wb}} + b_{i_{wb}}}, \frac{b_{i_{wb}}}{r_{i_{wb}} + g_{i_{wb}} + b_{i_{wb}}} \right)$$

$P_{normalized}$ is transformed to an HSV representation, P_{HSV}, which is further brightened by maximizing the V values for each pixel. Black strokes are identified in $P_{normalized}$ by thresholding it based on intensity to identify dark areas and producing a set of binary pixels P_{black}. For color pens, P_{HSV} is thresholded with a heuristically determined pen-specific hue range identifying (bright) blue, green or red pixels, thus producing P_{red}, P_{blue}, and P_{green}, respectively. The four binary images act as an input to tracing algorithm one by one.

Skeletonizing

Identification is based on the existence of dark or highly saturated colored pixels in the preprocessed image P_{bw}, which have been extracted during color-channel segmentation. Figure 7.6 (left) shows an overlay of P_{black}, P_{red}, P_{blue}, and P_{green} masked with ROI_{masked} for the upper right quadrant of the sample picture (white regions are excluded from skeletonizing). Preprocessing still leaves many artifacts in this quadrant due to the black cloth visible in Figure 7.3.

The skeletonizing algorithm takes each of the binary images as an input and extracts connected regions of foreground pixels ("blobs") $B = [b_1, \dots, b_n]$ with $b_i = [p_1, \dots, p_n]$ where each p_i is a binary pixel. To extract structure information, each b_i is skeletonized to a single-pixel width line $skel_i$ via the approach proposed by Saeed et al. (2010) and is then added to the set $Skel$.

Tracing and graph clustering

The pixels in each are classified as line end points (points 1, 7, 10 in Figure 7.7), crossing points (point 6 in Figure 7.7) or interior points depending on the foreground pixels in a 3×3 pixel neighborhood. The tracing algorithm creates a graph representation g_i consisting of line segments s_{i_a} by recursively traversing $Skel$ and following each $skel_i$ from an end/crossing point to the next end/crossing point. Each of these parts in a $skel_i$ constitutes a s_{i_a}. In Figure 7.7, a graph g_1 is shown consisting of s_{1_1}, which is located between point 1 and 6, s_{1_2}, which is located between points 6 and 7; and s_{1_3}, located between points 6 an 10. In addition to the structural information, each s_{i_a} comprises information on length, and an array of support points inside the segment (points 2-5, 8-9 in Figure 7.7), including thickness data of the line stroke in the non-skeletonized picture at these points (based on a distance transform of the binary picture (Fabbri et al. 2008)). All g_i are added to the set G_{raw} including information on their color based on the binary image they were extracted from.

A clustering step is applied on G_{raw} that aims to merge disconnected regions that are assumed to belong together. For each end point $p_{i_{end}}$ in a graph g_i, we search for graphs g_j with a point p_j being closer than a minimum distance. This allows us to join disconnected sketched lines and merge arrow tips that do not touch the line itself. We have heuristically determined a limit to 0.2 times marker height as providing good results. The resulting merged graphs are added to the set $G_{clustered}$.

Figure 7.6: Upper right quadrant of sample picture (left: input to skeletonizer, right: output of tracer)

Figure 7.6 (right) shows the graph set generated by the tracer for the upper-right quadrant of the sample picture (graphs thickened for better visibility). The graphs on the right have been created due to the misrepresented area of interest.

Connector and arrow tip detection

$G_{clustered}$ is used to identify the connection candidates: As a first test, graphs with an average thickness higher than a threshold are rejected (e.g., eliminating the artifacts in the top right image corner as visible in Figure 7.6, left). A number of rules are then applied to identify actual connections in $G_{clustered}$ that link two modeling elements e_i

and e_j. The rules used for connection identification take several factors into account. Most notably, connections are defined to end nearby modeling elements. Graphs are thus identified as connections if there are graph points outside a nearby region (suppressing local scribbles) and if it is nearby at least two modeling elements (suppressing loops). The threshold for "nearby" is implemented as a fixed ratio of the element size as extracted from *P*. In Figure 7.7, points 1, 2, and 5-10 are rated to be nearby an element. Points 1 and 6 are considered to be end points of a connection as they are located more closely to the border of the modeling elements than their neighbors. Successfully tested graphs are added to the connector set $Con = (con_1, \dots, con_n)$ and removed from the set $G_{clustered}$.

The algorithm also recognizes connections with multiple endpoints by following all line segments at intersections or forking points. Consequently, intersecting connections of the same color cannot be recognized, as they would be considered a single multiple endpoint connection. Intersecting connections thus have to be of different colors to be recognized correctly.

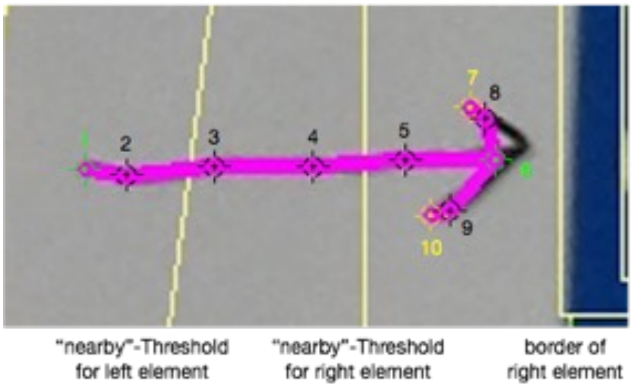

Figure 7.7: Detection of connections from identified segments

Each identified connection is additionally scanned for nearby line segments that could constitute an arrow tip, indicating directed connections (cf. points 7-8 and 9-10 in Figure 7.7). Here, rules take into account the length of potential line segments and the angle enclosed between them and the final line segment. This information is stored in dir_i and is added to con_i.

Graphs which do not start nearby a modeling element are not considered further during connection search. This creates a more robust behavior in case of the pictures containing content not belonging to the actual model. As an example, the pen located at the left border of the sample picture is contained in the *ROI*. Still, as none of the resulting graphs are located nearby an element, the resulting graphs were not considered further.

The final result of connection identification is shown in Figure 7.8. All connections have been successfully recognized, and the picture also shows no false-positive connections. The arrow tips also have been recognized correctly.

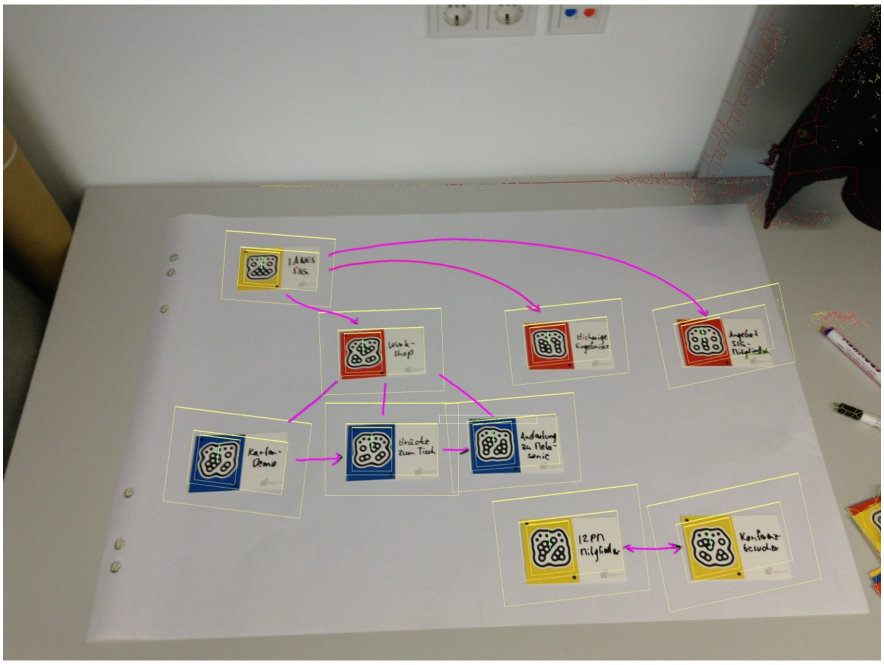

Figure 7.8: Overall recognition result

7.4.4.3 Identifying Connection Labels

Connection labels are extracted from $G_{clustered} \backslash Con$ after connector identification. For each graph in this set, a bounding box is computed and expanded by 80%. Graphs with dimensions over a heuristically determined threshold (half a modeling element height) are disposed. For the remaining graphs, all graphs in set Con are examined if at least one support point is located inside the bounding box. If so, a new candidate label $lcand_i$ is added to set L_{raw} (cf. Figure 7.9, label “4” recognized, label “not relevant” ignored by label recognition).

Figure 7.9: Detection of connection labels (left: recognized label, right: ignored graphs)

As labels can consist of several individual letters, represented by individual graphs, a merging stage iterates over set L_{raw} and the remaining graphs from $G_{clustered} \backslash Con$. Once a label candidate $lcand_i$ and a second graph have intersecting bounding boxes, the latter is merged into $lcand_i$. Label recognition thus operates incrementally in the surrounding region of a connection, i.e., it only requires the label to start in the region. As no letter recognition is currently performed, the identified labels are extracted as images. For each label, a rectangular bounding box is defined comprising all graphs identified to belong to the label, and the respective part of the picture is saved as an image named label_{i}.jpg for later reference, where i is a counter incremented for each label.

7.4.4.4 Multi-picture Extraction

When multiple pictures are used, the algorithm relies on the availability of a single overview picture. This overview picture, however, does not need to be explicitly marked as such. Rather, the picture with the highest number of identified elements is used as the overview picture. Model recognition is performed on each picture separately as described above. No pixel-based or conceptual stitching is performed in the current implementation. Consequently, no connections or labels that are spread over two pictures can be recognized. Added value, however, currently is generated for label extraction, where the label with the highest resolution is included in the final result.

More sophisticated multi-picture recognition is currently being implemented. By identifying overlapping areas of model parts in the extraction results of the single pictures, the constraint of having a single overview picture can be modified to only require overlapping areas between single pictures, thus allowing for arbitrarily sized models.

7.4.4.5 Model Refinement

Model refinement allows improving interactively the recognition results by manually providing further information about the model to be recognized. In its current implementation, this step is supported by features of a web-based platform. They allow replacing the extracted pixel-based labels with their textural representations (cf. Figure 7.10).

Figure 7.10: Interactive refinement of model information

The next iteration of the toolset will offer refinement support via a mobile interface, which allows providing feedback about the recognition results already during capturing, enabling immediate user reaction on results with insufficient quality. Current prototypes of the recognition engine already allow for live skeletonizing of a video input stream, which enables directly assessing the recognition quality to be expected during capturing. However, results are too preliminary here to elaborate on this improvement of tool handling.

7.4.5 Integration with Overall Set of Instruments

The results of model recognition are stored as XML files using the same data format as the other modeling tools in the overall KLC-based system (cf. Section 7.2). They can thus be directly used for import to the interactive tabletop modeling system. By making use of the functionality provided there, models can be stored in other file formats to be compatible for legacy tools, like the concept mapping tool CMapTools (Canas et al. 2004).

The XML output focuses on representing the conceptual structure of the model and largely omits its layout. In particular, connections are only represented by their end-points, and lack information on the connection path. For use cases, where exact presentation of the original layout is required, an SVG (scalable vector graphics) output is generated to provide a model version that exactly resembles the original layout of the paper-based model, including the identified connection graphs. In combination with the extracted modeling elements and connection labels, this information can be used to digitally re-create the original model in both layout and logical structure. This representation, for example, is used for display and exploration of models in the content repository used to share organizational content in the KLC.

Recognized models are provided to the other tools via a REST API (Representational State-Transfer) and thus rely on standard technologies (HTTP-requests) for interoperability. The API exposes the model in different formats (XML-based model exchange format, SVG, unprocessed overview picture) as well as the extracted model parts (modeling elements, connection labels). It furthermore provides access to processing metadata in the form of an XML-based log-record. The API provides read-only access to the data, as the MoDig-engine acts as a provider for modeling information to other tools. For integration with external providers of pictures, such as the mobile capturing tool (cf. Section 7.2), an interface to push new pictures to the engine via a HTTP-POST request is provided.

7.5 Validation

The aim of the present research is to enable users to capture paper-based sketched conceptual models under uncontrolled conditions and extract digital model representations that can directly be used further in IT-based conceptual modeling tools. For this aim to be achieved, the system has to provide a level of recognition accuracy that requires minimal effort by users for continuing to work with the digitized version of the model. At the same time, users should be free from technical constraints on capturing to enable them to focus on their actual tasks. The validation of the proposed approach is thus carried out on two levels. First, we assess the recognition quality of the developed system in terms of accuracy of the identified model information. This assessment has been carried out with a set of sample pictures provided by potential users of the system. This part of the evaluation is described in the next subsection.

The second subsection provides insights in a field study, during which the system was operatively deployed in an organizational development workshop in a hospital. We report on the results of the workshop, how these were embedded in the operative IT systems and give an account on the users' experiences and expectations when using the system.

7.5.1 Evaluation of Recognition Quality

The aim of this chapter is to show the feasibility of a recognition engine for paper-based conceptual models captured by users under uncontrolled conditions. In order to allow for seamless integration of the developed tool in the mixed modality toolchain, the amount of recognition errors, which would require manual intervention for correction, need to be as low as possible. Recognition quality alone, however, does not determine the potential value of the tool in daily use. The actual effort for transformation is a better metric for that. The less effort (in terms of time necessary for transformation) is required, the higher the potential value of the tool for users.

The baseline for recognition quality and transformation effort is the manual transformation of the paper-based models to digital models by a human actor. Recognition speed is not critical, as the use case does not comprise synchronous operation of paper-based and digital tools.

7.5.1.1 Methodology

Recognition quality is assessed quantitatively by calculating the recognition accuracy of MoDig engine in relation to human transformation of the models as a baseline.

Each model is analyzed by a human actor regarding the amount of model elements, connections, and arrow tips it contains (these categories are referred to as items in the following discussion). The distinction is made as those types are algorithmically treated differently during recognition. Connection labels were also considered for analysis, but were later removed, as they were hardly being used in the available sample models. The quality of their recognition is discussed qualitatively in the report on the field study in the next section. For all item types, accuracy is calculated by calculating the sum of missing (i.e., false negative) and superficial (i.e., false positive) recognized items and dividing this value through the amount of items identified by the human actor.

The interpretation of results also needs to take into account the *effort necessary to recognize and correct errors in the extracted model*. The effort is quantified by the amount of time necessary to compare the extracted model to the original picture(s), search for errors, and correct them. The baseline for comparison is manual transformation of the model. For each extracted model, the time needed for manual transformation, as well as the time needed for finding and correcting errors in the automatically extracted model, are measured. Aside from this, the remaining errors are counted for both, manual transformation and correction of automatic extraction. In order to minimize the effects introduced by the performance of individual users, the transformation and error correction is carried out on the same set of pictures by several users independently. The system is considered to provide the intended value, if the time needed for correcting recognition errors is significantly lower than the effort required for manual transformation, while the remaining errors must not significantly exceed those introduced in manual transformation.

7.5.1.2 Data Collection

Data for the assessment of *recognition quality* has been collected over a duration of 3 months in field studies. Practitioners in organizational development have been asked to provide real-world examples of how they would use the system in their daily practice. The practitioners were recruited from the special interest group of the research project the present work was embedded in. Consequently, all of these practitioners had prior experiences with the interactive tabletop modeling system, and thus were knowledgeable in the general modeling approach. None of them had experiences with, or prior knowledge in, IT-based image recognition and its technical requirements and constraints. They were only instructed to take pictures with their commonly used camera (or smartphone). Of the provided images, only those in which all items were also readable and interpretable for humans were used, as human interpretability was used as a baseline. Furthermore, images that violate the present fundamental recognition constraints of the modeling engine (no overlapping modeling elements, no intersecting connections of the same color) have been removed. Overall, 43 models overall comprising 936 items (338 modeling elements, 320 connections, 278 arrow tips) created collaboratively by 73 different people and photographed by 12 different people were considered for evaluation of recognition quality. The median number of modeling elements per model amounted to 8 (min=3, max=16); for connections the median was 8 (min=0, max=15), and for arrow-tips the median was 7 (min=0, max=14).

Data for the assessment of *effort for transformation* have been collected in a quasi-experimental setup. Fourteen users (3 females, 11 males, with age ranging between 22 and 42 years) with a mixed amount of digital conceptual modeling experiences (4 persons with several years of experience, 7 persons with limited experiences, and 3 persons without any conceptual modeling experiences) were recruited as participants. Three models were selected from those collected in the field studies based on the archived recognition quality: one of the models with no recognition errors, the model with the highest overall error rate, and a model with an of overall error rate near the average number of errors. As an additional selection criterion, the selected models had to contain at least 5 modeling elements, 5 connections and 4 arrow tips (each of this numbers designating the 25% quartile for each set of items). For each of these models, a digital representation in a computer-based conceptual drawing tool (http://draw.io) was created based on the recognition results. Those models consequently contained only elements recognized by the MoDig-engine.

For completing their tasks, the users were provided with printouts of the source pictures. They were asked to make sure that the digital representation resembled the model contained in the picture in terms of conceptual structure (i.e., modeling elements, connections, and arrow tips) as well as in layout. Textual transformations of captions on modeling elements or connections were omitted. If discrepancies were found, the users were instructed to correct them in the editor. The time required to complete this task was measured. Afterwards, users were asked to manually create a digital representation of the model from scratch using the same tool. The time required to complete this task again was measured. Upon completion, the remaining errors in the manually created digital representation as well as the automatically extracted and subsequently corrected digital representation were counted.

7.5.1.3 Results

The metrics for *recognition quality* are summarized in Table 7.1. It shows the minimal, maximum and median accuracy for each item type and for the sum of all items. In addition, the mean values and the standard deviations have been calculated to give an idea about the overall distribution.

Table 7.1: Accuracy for different item types

Accurracy	Elements	Connections	Arrowtips	Overall
Min	91,7%	7,7%	25,0%	48,6%
Median	100,0%	100,0%	85,7%	95,2%
Max	100,0%	100,0%	100,0%	100,0%
Average	99,8%	88,8%	82,9%	90,3%
StdDev	1,3%	21,5%	20,8%	13,7%

The average accuracy of 90.3% in an averagely sized model [based on the collected data, models overall on average contained around 22 items (modeling elements, connections and arrow tips)] amounts to approximately 2 errors per model. For interpretation, it is necessary to recognize that errors do not occur independently of each other. If a connection is not recognized, its respective arrow tips also cannot be recognized, causing follow-up errors. The same is true for recognition errors of modeling elements, which cause all attached connections and their arrow tips to be missed.

The low minimum accuracy for connections (7.7%) is attributed to a model which has shown a high number of false-positive recognition results for this item type. This was caused by connecting modeling elements that were positioned so closely to each other, so that their “nearby” region overlapped. The connections were still recognized appropriately. However, users also added labels to the connections, which consequently also were located in both nearby regions at the same time. The graphs of the labels were thus identified as connections by the recognition algorithm, and, in this way, nearly doubled the number of recognized connections. The same model has caused the minimum accuracy for arrow tips for the same reasons.

Figure 7.11 gives a graphical visualization of the observed overall error rates as well as for each item type. The x-axis is segmented in discrete categories for the error rate in steps of 10%. The y-axis shows the number of models that have an error rate in the respective interval.

As can be seen in Figure 7.11, 17 out of 43 models have been recognized without any error (40%). Thirty-three models (77%) have been recognized with an accuracy of 90% or higher. The accuracy does not drop below 65% for 88% of the models.

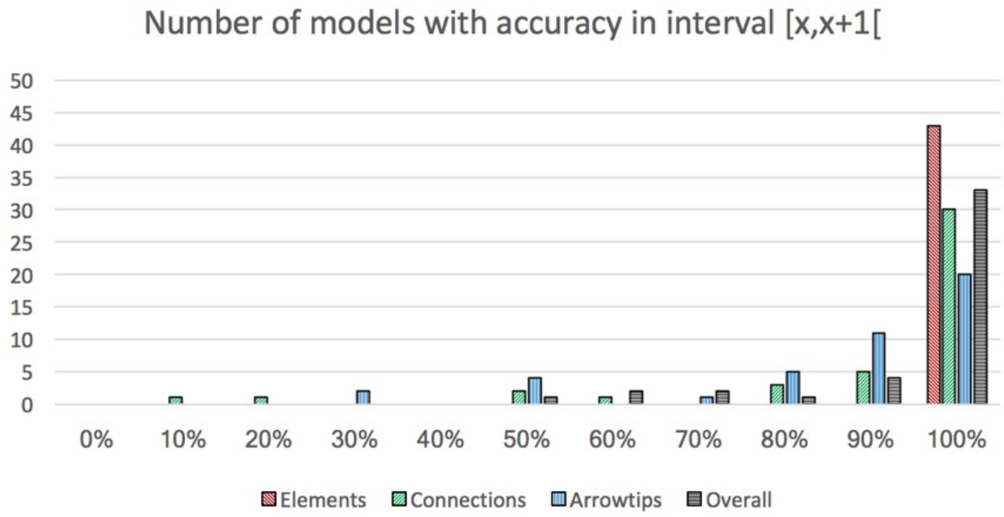

Figure 7.11: Distribution of accuracy for different item types

A separation by item categories shows a more differentiated picture. For modeling elements, 98% of the models have been recognized without any error, and no model drops below an accuracy of 90%. In absolute numbers, this is caused by a single recognition error in a single model out of 43. The approach of using optical markers to reliably identify modeling elements can thus be considered successful. For connections, 30 models (70%) have not shown any recognition errors. Accuracy above 80% (i.e., 1-2 recognition errors in averagely sized models) is achieved for 81% of the models. The amount of models without any recognition errors for arrow tips is lower than in the other categories (18 models, 42%). This, however, is mainly caused by follow-up errors of unrecognized connections, which lead to one or multiple unrecognized arrow tips. Forty models (86%) show an accuracy of more than 60%. When compensating for the calculations for follow-up recognition errors, the accuracy for arrow tips never drops below 75% (amounting to 2 recognition errors in absolute numbers), with 26 models (60%) showing no recognition errors.

These numbers show that—while recognition quality of modeling elements hardly leads to any error—the error rate for connections and arrow tips still require manual checking and correction by the user. The system can only be considered successful, if the compensation of recognition errors causes significantly less *effort for transformation* than manually transforming the models. In the following, we present the results of the quasi-experiment that has been carried out for assessing this effort as described above.

Table 7.2 and the boxplots in Figure 7.12 show the descriptive parameters for the distributions of task completion time in seconds for each task (x_corr denotes the correction task, x_self denotes the manual redrawing task for each model). The wide range of required completion time can be attributed to the different amounts of effort invested by the participants to resemble the model layout as closely as possible and their different levels of experience in computer use. None of the models contained any conceptual errors after completion of the tasks. Layout resemblance varied to a large degree in the manually created models, but no severe layout deviations were recognized. Further analysis thus focuses on task completion time as a metric for transformation effort.

Learning effects that resulted in more efficient use of the drawing tool were identified as a confounding variable. Its effect was minimized by confronting users with an up-front training task to get used to the tool, and the fact that only task completion times of successive tasks were compared pairwise, and consequently were subject to similar learning effects.

Table 7.2: Task completion time for error correction and manual transformation

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
m1_corr	14	10.0	531.0	83.714	133.4117
m1_self	14	75.0	638.0	198.214	161.3053
m2_corr	14	27.0	271.0	87.714	79.7799
m2_self	14	53.0	295.0	148.714	77.8415
m3_corr	14	149.0	346.0	223.786	62.4465
m3_self	14	181.0	558.0	323.643	119.0460
Valid N (listwise)	14				

For each pair of variables (x_corr and x_self), it has been tested whether x_corr was significantly lower ($p<0.05$) than x_self. For model 3 (that with the highest error rate), the completion times for both tasks are normally distributed (tested with Kolmogorov-Smirnov test for one sample). This is not the case for the models ($p<0.05$). Consequently, a paired samples one-sided t test was performed and showed, that the correction of model 3 took significantly less time than manual transformation ($p<0.05$).

For model 1 (without any recognition errors) and model 2 (with an average number of recognition errors), significance was tested with a one-sided Wilcoxon test for paired samples. Both tests showed that correction for each of the models took significantly less time than manual transformation ($p<0.05$).

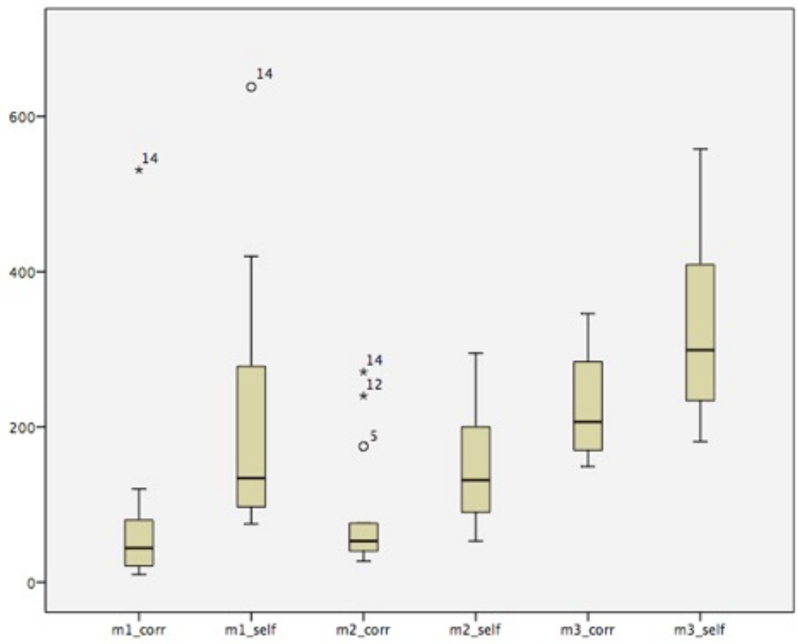

Figure 7.12: Distribution of task completion times in seconds

In addition, qualitative feedback was collected from the users performing the transformation. Here, we summarize the statements that were given by at least 3 users. Independently of the time required for transformation, several users stated that they found the correction of the recognized model cognitively less demanding than drawing it from scratch, as the already available elements provided anchor points for easier orientation. Users also stated that they considered it infeasible to manually create models that resemble the original layout as closely as the recognized model has done. As a suggestion, several users stated that they found identification of false negatives (i.e., missing items) less demanding than the identification of false positives (i.e., superficial items). They consequently prefer conservative recognition that rather produces false negatives (i.e., drops actual items) than identifying false positives (i.e., adding superficial items), as the former can be recognized more easily. Error correction, however, has appeared to be faster in the case of false positives (i.e., deleting superficial items is faster than adding missing ones). Thus, identifying the optimal thresholds for item recognition does not appear to be trivial and might even be depended on by the users who are operating the system. As this aspect only has been addressed in qualitative statements so far, it requires further examination in future research.

7.5.2 Field Study

The field study has been performed in the healthcare sector involving in-house organizational developers. They support clinics in reflecting and re-designing work procedures. Development projects are collaboratively designed with each clinic and subsequently managed by the organizational developers. The descriptive investigation sought to confirm and extend the previously performed Value Network driven design of work processes (cf. (Stary 2014)) by semi-automatically capturing evolving structures of work processes. Even though the created models have no formal meaning, they provide a key memory for documenting and sharing work knowledge, both in terms of results and process history (cf. (Hayes et al. 2005)). For this reason, the models were not only captured in their final version, but also in intermediate steps that were considered critical to understand the process of model development.

The model elements were used to visualize relevant concepts within the work process. The terms used to denote concepts referred to roles (e.g., physician), tasks (e.g., treatment), and/or documents/data (e.g., a patient record). The process designs were based on named connections drawn between the modeling elements representing the concepts (e.g., indicating a sequence of steps). In order to overcome experienced shortcomings when capturing medical processes, in particular with respect to critical procedures (Christov et al. 2008), the meaning of encoded card items and relations has been assigned by the participants.

For modeling, the participants were provided with white flipchart paper, the modeling cards including the codes required for recognition, and appropriate pens. They were instructed on how to create a model and were asked to use different pen colors, connection shapes, element positions, and patterns. Then, 3 organizational developers began to collaboratively design a process, namely how a patient should be handled in a clinic.

In doing so, they created two models sketching two variants of the relevant tasks and their accomplishment (cf. Figure 7.13). The participants used red, blue and black pens, as well as various styles in writing and denoting items, in particular, connections. Modeling elements encoded primarily task-specific activities and roles, whereas connections encoded directed relations without label (explicit meaning), sequence numbers, and context information that were considered relevant for handling incoming patients.

Each model was pictured using a mobile phone camera, and processed by the MoDig engine before being displayed for further editing in an external tool (CMapTools; cf. (Canas et al. 2004)). The recognized elements were compared to the originally created maps, as the purpose of the descriptive investigation was to test the quality and effective use of the results for the participants.

7.5.2.1 Recognition Result

The result of model recognition for the two produced is shown in Figure 7.13. The left image is referred to as "Plan A" in the following discussion, whereas the right image is labeled "Plan B". The quantitative metrics given in the following refer to both pictures. All 30 modeling elements have been recognized correctly (accuracy: 100%). Of the 25 connections, 2 have not been recognized, and no false-positive connections were identified (accuracy: 92%). The connections labeled with "6" in Plan A and "8" in Plan B have been omitted, as one of their ends was placed slightly outside the nearby region of the modeling item it should have been attached to. The heuristics used to identify nearby connections have been improved since the study was conducted and do not lead to this recognition error anymore in the current implementation.

Each connection was assigned a direction, i.e., sketched with a single arrow tip. Accordingly, 25 arrow-tips should have been identified. As arrow tip recognition is dependent on the recognition of the according connection, the arrow tips of the two missing connections were not recognized. All other arrow tips have been identified correctly, and no false-positive arrow tips were identified (accuracy: 92%).

The recognition of connection labels shows a weaker performance. For Plan A, 13 labels have been added to the model (several numbers, used redundantly, and two explanatory text labels). The recognition engine could not identify any of these labels. For Plan B, 13 labels have been added to the model (numbers 1-11, and two explanatory text labels). The recognition engine was able to correctly identify 5 labels ("1", "2", "3", "4", "9"). The other labels in Plan B have not been recognized. This amounts to an accuracy of 19%.

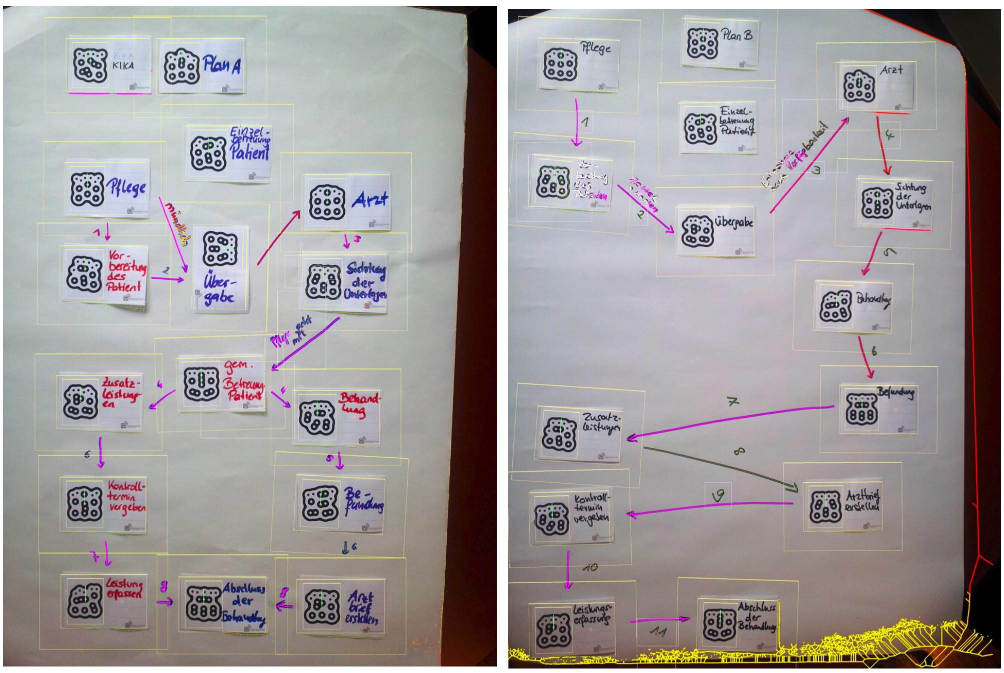

Figure 7.13: Recognition results for models created in the field study

Two different reasons for this poor performance could be identified in ex-post analysis. In Plan B, the labels 5-9 and 10-11 as well as the explanatory label of connection 3 were placed slightly outside of the regions considered to contain potential labels for the according connections. The heuristics used to identify nearby labels have been improved since the study was conducted and do not lead to this recognition error anymore. The missing recognition of the explanatory label in Plan B and all of the missing labels in Plan A are caused by the assumption of the interpretation algorithm that labels will be placed outside the "nearby" region of modeling elements. While this assumption seemed reasonable based on the available testing data, the field study has shown the inappropriateness of this assumption. When modeling items are positioned nearby (as is the case in Plan A), labels are generally located within one of the concerned "nearby" regions, preventing their recognition. While this has been corrected in the current implementation, it did have implications in the field study and thus is reported here accordingly.

7.5.2.2 Further Use of Workshop Results

The recognized models were loaded on a Comprehand Table in a subsequent session for further reflection. The recognition errors were corrected by the users themselves directly on the table. The labels, which are attached to modeling elements and connections as images directly after import, were replaced by textual representations. Content-wise, no significant changes were made to the models aside from minor rearrangements affecting the spatial layout of the models.

The organizational developers managed all of the models they were working on within in a repository provided by a CMapTools (Canas et al. 2004) server. Consequently, the resulting model was exported to the legacy file format used to store and exchange models in CMapTools. From this repository, the models were also available for the operatively affected people in the clinic, which they used as a point of reference for their work processes, to assess which variant worked better in daily practice. In a subsequent workshop a few weeks later, the models were again opened on the Comprehand Table for reflection on the variants.

The integration with the locally used ensemble of tools and the contribution to the overall workflow worked as intended in the field study. Still, the organizational developers refrained from permanently deploying the card-based modeling tool, as their workshop setup required immediate availability of digital model versions and did not allow for manual correction of recognition errors. They consequently chose to remain with the workshop setup based on the interactive tabletop modeling interface, although they recognized that the required organizational and technical effort was much higher than for the card-based system.

7.5.2.3 Qualitative Feedback of Users

In a final step, the users participating in the field study provided qualitative feedback on the use of the system in a focus group. The following critical factors for permanent deployability of the MoDig tool were identified in this setting. First, the system as a whole was rated as easy to use. The required workflow was perceived to be understandable, but still considered rather inconvenient and cumbersome to use. This was mainly attributed to the fact that taking pictures and uploading them to the recognition systems was not integrated in a single step (i.e., in one app supporting the whole workflow).

The participants were willing to accept some trade-off due the 'low-cost approach', as they termed it, but still expected a more seamless experience during capturing and more immediate feedback on the archived recognition quality.

Second, the participants felt disturbed by the cognitive effort to be spent on positioning elements in the course of drawing, in order to avoid recognition problems due to the limitation of the deployed version of the recognition engine. In particular, they criticized the required accuracy in ending drawn connections nearby an element. The deployed version showed problems in recognizing connections that ended slightly too far away from elements. In combination with cards that slipped out of their initial position during modeling this caused interruptions in the modeling flow that were considered to be hardly acceptable in everyday use.

Despite these shortcomings, the participants felt the systems could reduce the initial effort required for digitizing the model. However, they expected a more reliable recognition of modeling elements and connections in order to focus on content entries, either using the editor of the system or any other third-party modeling tool after exporting the data.

7.6 Conclusion

In the present chapter, we have introduced a system to support the user-driven capturing and automated recognition of paper-based conceptual models. The aim was to develop a system that can be operated by end users with commonplace capturing devices such as smartphone cameras. The model recognition engine has been designed to process such pictures and provide the results in a format that is interoperable with other tools in the overall system environment, which supports organizational learning processes. The system has been evaluated regarding its recognition quality and the required effort to compensate for potential recognition errors. These results show that the system has achieved its fundamental aims, while still being negatively affected by the technical limitations of the current version. Both, capabilities and limitations also could be confirmed in the field study. Consequently, the contribution of the present work is the introduction of a recognition system for conceptual drawings, which was explicitly designed to be operated with uncontrolled input created by users without technical background or knowledge. In comparison to existing related research, the proposed system advances the state of the art by introducing an approach for extracting conceptual model information from paper-based sketches captured under uncontrolled conditions in a fully integrated, directly deployable system. Related work so far has always assumed the availability of a digital representation of the sketch (e.g., created on tablet computers) (Wüest et al. 2015) or digitization to be performed under controlled conditions (Jiang et al. 2011). Attempts for tackling the challenge of uncontrolled capturing so far have only been tested in experimental settings (Ghorbel et al. 2015). Our approach has shown appropriate recognition performance in a quasi-experimental evaluation, and has demonstrated its feasibility for real-world use in a field study.

The research presented here has several limitations. First, in terms of tools performance, the quality of recognition especially for connections between model elements is insufficient, especially when the source pictures suffer from suboptimal conditions (mainly in terms of shadows caused by lighting and poor quality of the pens used for drawing connections). This hampers unattended deployment for end users, who are not necessarily aware of the current limitations. Second, the integration in the overall set of tools is still limited from a user's perspective, which limits acceptance and usability for novel users. Third, from a methodological point of view, the system requires a more extensive evaluation to examine the recognition workflow from both user and technical perspectives, to develop informed design hypotheses to further support measures and improvements of recognition quality.

These limitations will be addressed in future research and development. We plan to improve recognition quality by using more robust connection tracing algorithms as identified in Section 7.3. Furthermore, the heuristically determined parameters for the recognition modules (in ROI detection, graph tracing, and recognition of arrow tips and labels) will be systematically assessed based on an extended database of sample pictures to improve overall recognition accuracy. The capabilities of model extraction from multiple pictures will be developed further to avoid the need for a single overview picture, which currently limits the maximum model size. Finally, integration in the overall set of tools will be made more transparent by the provision of a mobile app as a gateway for capturing, recognition and model refinement. This gateway is envisioned to interactively guide the capturing process in a later revision, intertwining it with model recognition to provide immediate feedback on the recognized result and allow for in-situ revision of the captured models, as outlined by Ghorbel et al. (2015). Interactive capturing will also allow implementing features for tracing design history, which was suggested to be supportive for end user-driven design by Mangano & Sukaviriya (2010).

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9 Annex I - Original Publications

9.1 Included Articles

The following publications are included in the present work and together constitute its core contribution:

- Oppl, S. (2016). **Articulation of work process models for organizational alignment and informed information system design**. Information & Management, 53(5), 591–608. http://doi.org/10.1016/j.im.2016.01.004
  - Journal Impact Factor 2015: 1,919
  - VHB JourQual3: B
  - ACPHIS Ranking 2013: A*
- Oppl, S., & Alexopoulou, N. (2016). **Linking natural modeling to techno-centric modeling for the active involvement of process participants in business process design**. International Journal of Information System Modeling and Design, 7(2). http://doi.org/10.4018/IJISMD.2016040101
  - Journal Impact Factor 2015: not ranked
  - VHB JourQual3: not ranked (has not received sufficient votes), indicative: C
  - ACPHIS Ranking 2013: not ranked
- Oppl, S. (2016). **Evaluation of collaborative modeling processes for knowledge articulation and alignment**. Information Systems and E-Business Management, in press. http://doi.org/10.1007/s10257-016-0324-9
  - Journal Impact Factor 2015: 0,953
  - VHB JourQual3: C
  - ACPHIS Ranking 2013: B
- Oppl, S. (2016). **Supporting the collaborative construction of a shared understanding about work with a guided conceptual modeling technique. Group Decision and Negotiation**, in press. http://doi.org/10.1007/s10726-016-9485-7
  - Journal Impact Factor 2015: 1,312
  - VHB JourQual3: B
  - ACPHIS Ranking 2013: A

- Oppl, S., Stary, C., & Vogl, S. (2016). **Recognition of paper-based conceptual models captured under uncontrolled conditions**. IEEE Transactions on Human-Machine-Systems, in press. http://10.1109/THMS.2016.2611943
  - Journal Impact Factor 2015: 1,800
  - VHB JourQual3: not ranked
  - ACPHIS Ranking 2013: not ranked

9.2 Further related Articles

Aside the five articles listed above that constitute the core of this work, a number of other articles has been published in peer-reviewed proceedings of scientific conferences and workshops, which focus on specific parts of the developed set of artifacts or document the development of the design theory. They are listed in the following chronologically with a brief account on their contribution:

- Oppl, S. (2011). **Subject-oriented Elicitation of distributed Business-Process Knowledge**. Proceedings of the 3rd Conference on Subject-Oriented Business Process Modelling (S-BPM ONE 2011), LNCS vol. 213, 16–33. Springer. http://doi.org/10.1007/978-3-642-23471-2_2
  - First article to outline the multi-perspective approach on collaborative work modeling also adopted in the final artifact.
- Neubauer, M., Oppl, S., Stary, C., & Weichhart, G. (2013). **Facilitating Knowledge Transfer in IANES - A Transactive Memory Approach**. In R. Howlett, B. Gabrys, K. Musial-Gabrys, & J. Roach (Eds.), Innovation through Knowledge Transfer 2012 (Smart Innovation, Systems and Technologies, Vol. 18, pp. 39–50). Springer. http://doi.org/10.1007/978-3-642-34219-6_5
  - Article discussing the integration of collaboratively externalized information represented in conceptual models as a part of organizational memory systems.
- Oppl, S. (2013). **Towards Role-distributed Collaborative Business Process Elicitation**. In A. Nolte, M. Prilla, P. Rittgen, & S. Oppl (Eds.), Proceedings of the Workshop on Models and their Role in Collaboration (pp. 33–40). ceur-ws.
  - First article to discuss the methodological implications of different negotiation patterns when aligning different views on a work process.
- Oppl, S., & Stary, C. (2014). **Facilitating shared understanding of work situations using a tangible tabletop interface**. Behaviour & Information Technology, 33(6), 619–635. http://doi.org/10.1080/0144929X.2013.833293
  - Article reporting on the foundations of the setting-the-stage phase preceding multi-perspective articulation of collaborative work. Argues for the relevance of physically creating model representations for mental model externalization and alignment and introduces a tangible tabletop interface supporting these processes.

- Oppl, S. (2015). **Articulation of subject-oriented business process models**. Proceedings of S-BPM ONE 2015, 1–11. ACM Press. http://doi.org/10.1145/2723839.2723841
  - Article describing the set of instruments necessary to perform multi-perspective modeling without direct technical modeling support (based on cardboard cards), technically extract conceptual model information using image recognition techniques and allow for model elaboration using virtual enactment. Gives a detailed account on transformation from modeling structures used for articulation and alignment to S-BPM models used for elaboration through enactment.
- Oppl, S. (2016). **Selbstgesteuerte Reflexion und Gestaltung von Arbeitsprozessen**. Momentum Quarterly, 5(4).
  - Article summarizing the articulation and alignment methodology in German language, explicitly focusing on the development of the design theory grounding the chosen approach to work process articulation. Also discusses the implications of the methodology from the perspective of workers' empowerment.