The Modeling Mind: Behavior Patterns in Process Modeling*

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Abstract. To advance the understanding of factors influencing the quality of business process models, researchers have recently begun to investigate the way how humans create process models—the process of process modeling (PPM). In this idea paper, we subscribe to this human–centered perspective of process modeling and present future research directions pursued in the vision of Modeling Mind. In particular, we envision to extend existing research toward PPM behavior patterns (PBP) that emerge during the creation of process models. Thereby, we explore PBPs by triangulating several quantitative and qualitative research methods, i.e., integrating the modeler's interaction with the modeling environment, think aloud data, and eye movement data. Having established a set of PBPs, we turn toward investigating factors determining the occurrence of PBPs, taking into account modeler–specific and task–specific factors. These factors manifest as modeling expertise, self–regulation, and working memory capacity. In a next step, we seek to investigate the connection between PBPs and process model quality in terms of syntactic, semantic, and pragmatic quality. These findings, in turn, will be used for facilitating the development of customized modeling environments, supporting the process modeler in creating process models of high quality. Through this idea paper, we would like to invite researcher to join our research efforts to ultimately arrive at a comprehensive understanding of the PPM, leading to process models of higher quality.

Key words: Process of Process Modeling, PPM Behavior Patterns, Business Process Modeling

1 Introduction

For decades, conceptual models have been used to facilitate the development of information systems and to support practitioners when analyzing business domains [1]. Recently, particularly *business process models*, or process models for short, have raised significant interest due to their critical role for the management

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of business processes [2]. For instance, business process models are used to support the development of process–aware information systems, inter–organizational workflows, service–oriented architectures and web services [3]. Additionally, the growing importance of business process management has influenced how conceptual modeling is taught, as business process management has been adopted in today's university curricula [4]. Considering the intense usage of business process modeling, the relevance of process models has become obvious. Yet, industrial process models display a wide range of problems [5], confirming that an in–depth understanding of factors influencing process model quality is required.

In response to the demand of process models of high quality, researchers recently have begun to take into account the processes involved in its creation. In general, as illustrated in Fig. 1, the *process model development lifecycle* involves several stakeholders, such as domain experts and system analysts, who drive the creation of the process model in *elicitation phases* and *formalization phases* [6]. In the *elicitation phase*, information from the domain is extracted by *domain experts* and used in the *formalization phase* by *system analysts* (*process modelers* in our context) for creating a formal process model [7]. Since requirements evolve over time, model development usually comprises *several iterations* of elicitation and formalization, resulting in an evolving process model.

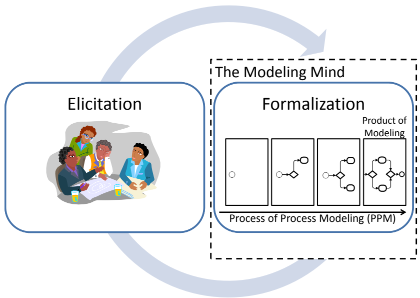

Fig. 1. Model Development Lifecycle

For the creation of process models that satisfy stringent quality requirements, such as correctness, comprehensibility and maintainability, significant modeling skills are indispensable [8]. These quality demands, in turn, have sparked significant research regarding process model formalization, mostly focusing on the *product of a process modeling endeavor* (e.g., [9, 10]). Recently, researchers have started to broaden their perspective from the *product*, i.e., the process model, toward the *process modeling act* (e.g., [11, 12]). Thereby, research focuses on the *formalization*, in which a process modeler constructs a process model reflecting a given domain description—denoted as *process of process modeling (PPM)* (cf. [7]). So far, research on the PPM has focused on recording the modeler's interactions with the modeling environment. For instance, researchers have observed differences in the way process modelers create process model [12] and suggested the existence of *patterns of behavior* (denoted as PPM Behavior Patterns, or PBPs for short) [12, 13]. For instance, it has been observed that some modelers start modeling immediately by adding elements to the model, while other modelers invest more time in understanding the modeling task before adding model elements [12]. Likewise, [13] observed that modelers working on specific, bounded parts of the model and finishing them before working on another part, tend to produce process models of higher quality [13]. Hence, we argue that the PPM provides an emerging, yet promising research direction for obtaining a better understanding of factors influencing the quality of process models.

1.1 Problem Statement

While prior research has advanced the understanding on how process models are created, several challenges remain. First, insights are solely based on analyzing the modeler's interactions with the modeling environment (e.g., adding, deleting, and moving nodes or edges), which allows only for a partial understanding of patterns of behavior [12]. Particularly, phases of inactivity with the modeling environment, e.g., when understanding the problem, can only be approximated. Thus, strategies modelers use during such phases (e.g., understanding the problem and mapping domain knowledge to modeling constructs [14]) cannot be investigated. Also, validation activities where modelers check whether the created process model complies with the requirements remain undiscovered. Therefore, challenge C_1 describes the need to identify patterns of behavior during the PPM.

Second, while the results reported in [12] give indications that the PPM is influenced by *modeler–specific characteristics* (inherent to a modeler irrespective of the modeling task) and *task–specific characteristics* (depending on the modeling task), the exact factors determining differences are hardly understood. Additionally, *contextual factors*, e.g., management approval (cf. [15]), might influence the creation of process models. In Modeling Mind, we focus on the formalization of process models based on a textual description, with the purpose of documenting the specification. Therefore, only contextual factors that might influence the formalization of process models are considered, e.g., modeling purpose [2]. *Modeler–specific characteristics* include process modeling expertise, domain knowledge, but also working memory capacity and the modeler's personality. *Task–specific characteristics*, on the contrary, are specific to the modeling task (e.g., the task's inherent complexity or the presentation of the task to the modeler) and determine the task's *cognitive load*. In case that a task's cognitive load exceeds the modeler's working memory capacity, errors are likely to occur [16]. Typically, the cognitive load caused by a modeling task is measured once at the end of the modeling task using self–rating. However, since challenges faced during modeling might influence the occurrence of PBPs and eventually lead to errors once working memory gets overloaded, knowing the evolution of cognitive load over time seems to be essential. Challenge C_2 therefore relates to the identification of factors determining the occurrence of PBPs. In the vision of Modeling Mind, we aim to investigate these challenges in the form of two research objectives:

Research Objective RO_1: Identify and assess PBPs for process model creation Identifying PBPs considering different ways of analysis, i.e., model interactions, think aloud data, and eye movement data.

Research Objective RO_2: Understand factors determining the occurrence of PBPs Understanding how factors, including modeler–specific factors and task–specific factors, influence the occurrence of the identified PBPs.

Summarized, the goal of Modeling Mind is to obtain an in–depth understanding of PBPs. For this purpose, Modeling Mind utilizes different perspectives on the PPM, such as the modelers' interactions with the modeling environment, think aloud data, and eye movement analysis. In addition, Modeling Mind aims for understanding how these patterns relate to process model quality and for deriving a set of modeling styles bundling commonly co–occurring PBPs. Moreover, Modeling Mind seeks to understand factors determining the occurrence of PBPs covering modeler–specific factors and task–specific factors. By providing a theoretical model describing PBPs during the PPM and factors influencing modeling styles, Modeling Mind can facilitate the development of customized modeling environments, better supporting the individual modeler. Further, a thorough understanding of the PPM enables the development of effective teaching methods helping future students to become skilled in the craft of modeling.

The remainder of the paper is structured as follows. Section 2 describes the state–of–the–art relevant for RO_1 and RO_2. Section 3 describes how we envision to investigate RO_1 and RO_2, whereas the paper is concluded in Section 4.

2 Relation to State–of–the–Art

In this section, the state–of–the–art is discussed. First, the focus is put on PBPs presented in literature, forming a basis for RO_1. Then, a list of factors potentially determining the occurrence of PBPs is presented for RO_2.

2.1 Research on PPM Behavior Patterns

Existing work on the PPM has focused on analyzing interactions with the modeling environment. For this purpose, Cheetah Experimental Platform (CEP) [17] has been developed, providing a basic modeling editor recording the modeler's interactions with the modeling environment. By capturing the interactions, the creation of the process model can be *replayed* at any point in time.[2] Subsequently, we discuss PBPs described in literature to build a starting point for the investigations on RO_1. While the presented list is certainly not exhaustive, it constitutes a starting point for the investigations in Modeling Mind.

$\boldsymbol{PBP_1}$ **Planning** [12] describes differences regarding the time it takes modelers to start working on the process model. Some modelers start right away adding model elements (PBP_{1a}), while others invest more time in gaining an understanding of the modeling task (PBP_{1b}). To operationalize this aspect, [12] defines the measure of *initial comprehension duration*, capturing the time before modelers start adding content to the process model. It seems that differences in initial comprehension duration are modeler dependent, i.e., modelers that spend much time on an initial comprehension phase for one task do the same when working on a different task.

[2] A replay demo is available at http://cheetahplatform.org

***PBP_2* Detours** While some modelers create a process model in an efficient manner without detours (i.e., superfluous modeling interactions), others require several attempts (including the deletion and re–creation of content) [18]. To operationalize this aspect, [18] suggests a measure called *process deviations* that is calculated as the sum of all delete operations and those adding operations that deal with the re–creation of content [19].

***PBP_3* Layout Behavior** In [12, 20] we observed modelers who carelessly put nodes on the canvas and draw straight connecting edges, resulting in poor layout and a low number of layout operations (PBP_{3a}). Also, [12, 20] reports on three strategies to come up with an appealing layout. The first strategy involves modelers that place elements at strategic places right from the beginning, making subsequent layout interactions unnecessary (PBP_{3b}). The second and third strategy involve modelers who carelessly put nodes on the canvas and perform layout operations later on, placing and arranging nodes and edges to achieve an appealing layout. Laying out is either performed continuously, leading to a high number of layout phases with a small number of layout operations each (PBP_{3c}) or toward the end of the modeling process all at once, resulting in a small number of layout phases with a high number of layout operations (PBP_{3d}). It could be shown that modelers with the desire to invest into good layout will persist in this intent [12], suggesting that layout preferences are also modeler–specific.

2.2 Research on Factors Determining the Occurrence of PBPs

The creation of a process model can be classified as a problem solving task [12, 20], an area of vivid research for decades in cognitive psychology. Therefore, we turn to cognitive psychology as a starting point for understanding the factors determining PBPs. Subsequently, a list of factors potentially influencing the occurrence of PBPs as well as measurements are presented. The presented list cannot be considered complete, but should rather provide a starting point for future investigation. Only contextual factors impacting the formalization of process models are considered, e.g., modeling purpose [2].

Modeler–specific factors In this section, a list of factors specific to the modeler are presented. Modeler–specific factors are inherent to the modeler, but not independent of the modeling task. For instance, existing domain knowledge is inherent to the modeler, but obviously only a factor if the domain of the modeling task matches or conflicts with the modeler's prior knowledge.

Process modeling expertise Even though the influence of modeling expertise on the PPM has not been investigated, research has demonstrated that modeling expertise (i.e., process modeling experience and knowledge) positively influences process model comprehension (e.g., [21, 22]). To assess modeling experience, often self-assessment questionnaires rating participants' knowledge on process modeling and their experience in process modeling are used [21]. Since the validity of self–assessment on theoretical modeling knowledge has been questioned [22], it is often complemented with a test on process modeling [23].

Domain knowledge and conceptual modeling Moreover, research has demonstrated the importance of domain knowledge for the understanding of conceptual models [24]. We speculate that similar effects also occurs for process modeling tasks. To assess domain knowledge, [24] suggests the usage of self–assessment questionnaires where participants rate their familiarity with the domain.

Working memory and complex problem solving tasks Working memory (WM) represents a construct that maintains and manipulates a limited amount of information for goal directed behavior [25]. WM defines a main construct in human information processing and is a central component for an understanding of inter–individual differences in process modeling. More specifically, during the PPM, WM is responsible for the representation and integration of information for an iterative construction of a mental, and in the following physical, process model. The capacity of WM (WMC) can be measured via complex span tasks [26]. There is strong empirical evidence that WMC predicts performance in tasks like, e.g., language comprehension [27], reasoning [28], and the integration of preexisting domain knowledge [29]—fundamental cognitive abilities relevant for the PPM.

Self–regulation and complex problem solving tasks Self regulation consists of two basic modes: *locomotion* and *assessment* [30]. Locomotion is characterized by instantaneous, straight, and action oriented behavior (*"Just doing it"*). Assessment refers to the critical, strategical cognitive planning and evaluation of a given situation (e.g., goals, given means to reach them, and alternatives, *"Doing the right things"*). A person with high locomotion and low assessment acts like a *"headless chicken"* (trial and error). A person with low locomotion and high assessment will put only little into action. Therefore, for high achievement performance, balancing locomotion and assessment is necessary [31]. Self–regulation can be measured with the Locomotion–Assessment–Questionnaire [30].

Task–specific characteristics Creating a process model from a given process description is not only influenced by modeler–specific characteristics, but also by characteristics of the modeling task. This influence is described by Cognitive Load Theory [16] as *cognitive load* on the person solving the task. The cognitive load of a task is determined by its *intrinsic load*, i.e., the inherent difficulty associated with a task and its *extraneous load*, i.e., the load generated by the task's representation [32]. In our context, *intrinsic load* is determined by the process to be modeled. It can be characterized by the size and complexity of the model structure and constructs [33]. In contrast, *extraneous load* concerns, for example, the presentation of the task to the modeler [10]. Additionally, the properties of the notational systems, i.e., the modeling notation and the modeling environment, affect the difficulty of the modeling task, e.g., due to notational deficiencies [34]. Moreover, related work has demonstrated the impact of activities' labeling style [35], secondary notation (i.e., layout) [21], and the influence of modularity [36, 37] on understandability. While the impact of various task extraneous characteristics on model understanding has been widely addressed, it is less understood how these factors impact the creation of process models. In general, research has shown that a high cognitive load increases the probability of errors, especially when the WMC is exceeded [16]. Cognitive load is typically operationalized as *mental effort* [32] and various measurement techniques can be applied, such as the measurement of the diameter of the eyes' pupil (*pupillometry*), heart–rate variability, and rating scales [32]. Especially pupillometric data and rating scales (i.e., self–rating mental effort) have been shown to reliably measure mental effort and are widely adopted [38].

3 Vision of Modeling Mind

This section describes how we *envision* the detection of PBPs within PPM instances[3]. First, techniques for detecting PBPs are presented in Section 3.1. Then, possible PBPs are presented in Section 3.2, addressing RO_1. Finally, the data analysis procedure for identifying the influencing factors for PBPs are described in Section 3.3, addressing RO_2. Prior research on PBPs has focused on analyzing the interactions with the modeling environment. While several PBPs could be observed, this rather narrow focus limits the options for analyzing the PPM. For instance, the distinction between understanding the problem and mapping the problem to modeling constructs [14] cannot be detected. Therefore, we intend to complement the analysis of the modeler's interactions with the modeling environment with *think aloud data* and *eye movement data*. Additionally, feedback from modelers is collected. This way, we hope to triangulate toward a more comprehensive understanding of the PPM.

3.1 Widening the Perspective of the PPM

In Modeling Mind we seek to widen the perspective on the PPM by taking additional methods of investigation into account. First, we adopt think aloud, asking modelers to verbalize their thoughts during modeling [39]. This allows us to draw inferences on how modelers arrive at their conclusion. For instance, using think aloud, the distinction between understanding the problem and mapping the problem to the modeling constructs can be investigated. Second, apparently modelers rely on visual perception for reading the task description and designing the process model when creating a formal process model. To investigate visual perception, we plan to adopt eye movement analysis, allowing to further investigate internal mental processes involved in modeling. For instance, it is known that high–resolution visual information input, which only occurs during fixations [40] (the modeler fixates the area of interest with the fovea), is necessary for reading text or identifying model elements. This, in turn allows for identifying specific areas of interest the modeler is focusing attention on, e.g., the task description, features of the modeling environment, or modeling constructs. Within these areas, eye fixations can be measured to identify the parts of the modeling environment modelers focus on, potentially pointing to challenging situations.

[3] A PPM instance constitutes one specific instantiation of the PPM.

Visualization of Model Interactions, Eye Movement Data, and Think Aloud Data To support the identification of PBPs, we develop visualizations enabling an integrated analysis of model interactions, eye movement data, and think aloud data. Subsequently, several potential visualizations are proposed.

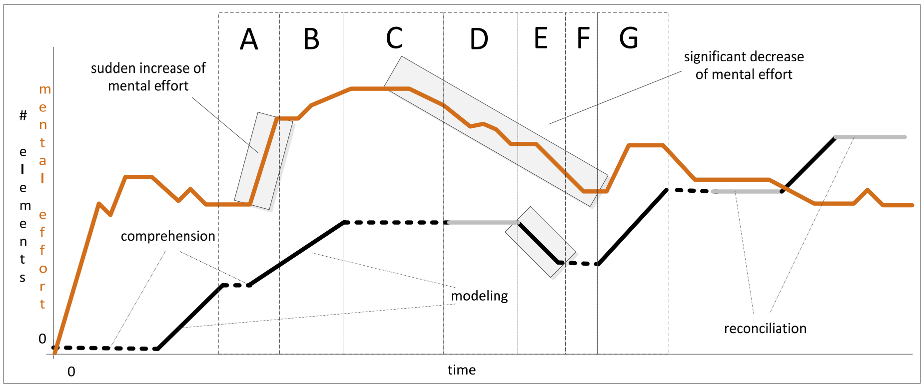

Fig. 2. MPD Including Mental Effort Visualization

Modeling Phase Diagrams with Mental Effort Modeling Phase Diagrams (MPDs) were proposed to visualize the interactions with the modeling environment to gain an overview of PPM instances [20]. For this, different activities during the formalization of process models are considered. Activities indicating modeling, such as adding content by creating nodes and edges, are mapped to *modeling* phases. Similarly, activities indicating clean–up, such as laying out the process model, are mapped to *reconciliation* phases. Finally, phases of inactivity usually indicate cognitive activities like understanding the problem, and hence are mapped to *comprehension* [20]. MPDs can be extended for displaying the modeler's mental effort, which was measured using pupillometry (cf. Fig. 2). Such a visualization allows for a quick overview of challenges faced during the PPM. For example, the PPM instance in Fig. 2 shows a sudden increase of mental effort in phase A. When looking at the corresponding visualization of modeling phases, it can be observed that this increase occurs in a comprehension phase. Fig. 2 further shows that mental effort remains high throughout the subsequent modeling phase B. The MPD suggests that the high mental effort might have caused a modeling error and the deletion of modeling elements in phase E and respective corrections during phase G (i.e., subsequent increase of number of model elements). It can be further observed that the mental effort started to decrease in phase C before the modeler started with the corrections and continued to decrease in phase D during which the modeler performed reconciliation interactions. This visualization could be complemented with an overview of significant changes of mental effort within a predefined timeframe (or timeframes with particularly high mental effort). Further, the visualization allows to jump to the corresponding part of the PPM instance using the replay feature of CEP.

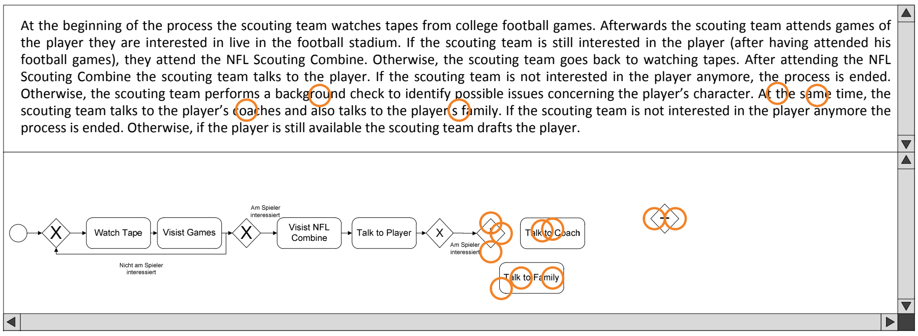

Fig. 3. Visualization of Fixations

Visualizing Fixations and Model Elements An increase in mental effort only indicates that the modeler perceived the modeling task more difficult in the current situation. Still, it does not allow for identifying the reasons for the problem. Therefore, mental effort analysis can be complemented with a visualization of the modeler's fixations. For this, an overlay for the modeling editor is designed, displaying fixations within, e.g., the last 10 seconds prior to the current position within the replay of the PPM instance. Fig. 3 illustrates the visualization, assuming that an increase in mental effort was identified using the visualization in Fig. 2. Then, CEP can be utilized for navigating to the position within the PPM instance with increased mental effort. The fixations within the last seconds reveal that few fixations were on the textual description, but several fixations were on the modeling canvas. This might indicate that the modeler had problems with the modeling constructs required for translating the information extracted from the textual description to the formal process model. Since the position of modeling elements as well as the textual description can be computed in an automated way, fixations can be automatically mapped. This, in turn, could be used to analyze whether modelers solely focus on the process model in reconciliation phases or whether they access the textual description to perform reconciliation.

Visualizing Mental Effort for Slices of the PPM Another visualization could—instead of dividing the PPM into different phases—focus on the the type of interaction with the modeling environment and slice PPM instances according to the modeling elements, e.g., XOR gateways. As illustrated in Fig. 4, insights can be gained into relations between mental effort and specific types of model interaction. Similar to Fig. 2, the visualization shows mental effort in a continuous manner. Further, interactions with the modeling environment passing a customizable filter, i.e., all interactions involving XOR gateways in Fig. 4, are displayed on a timeline. For instance, the example in Fig. 4 shows that two XOR gateways are created prior to the increase in mental effort in phase A. After a steep increase in mental effort in phase A, mental effort remains high in phase B. Further, in phase B a XOR gateway is removed and two new XOR gateways are created. This could indicate that the increase in mental effort is related to the

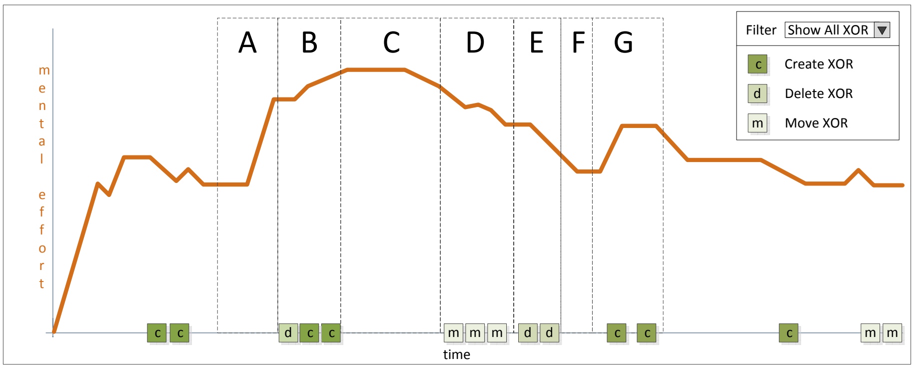

Fig. 4. Interactions with Mental Effort

XOR gateways. Next, several XOR gateways are moved in phase D, while mental effort decreases. In phase E, two XOR gateways are removed, while in phase G new XOR gateways are added to the process model causing an increase in mental effort. No major increases in mental effort related to the XOR gateways toward the end of the PPM instance can be observed.

Again, the visualization could be extended with measures linking the mental effort with modeling elements. For instance, timeframes surrounding the creation of the model element could be used for computing the average mental effort required for creating the model element. The selection of appropriate timeframes, however, needs to investigated first.

Visualizing Think Aloud Protocols Think aloud protocols can be visualized by utilizing the synchronized timestamps for positioning the verbal utterances within the MPD (cf. Fig. 5). By clicking on the visualization, the corresponding verbal utterance is displayed. Further, the verbal utterances can be filtered according to a previously manually constructed the coding.

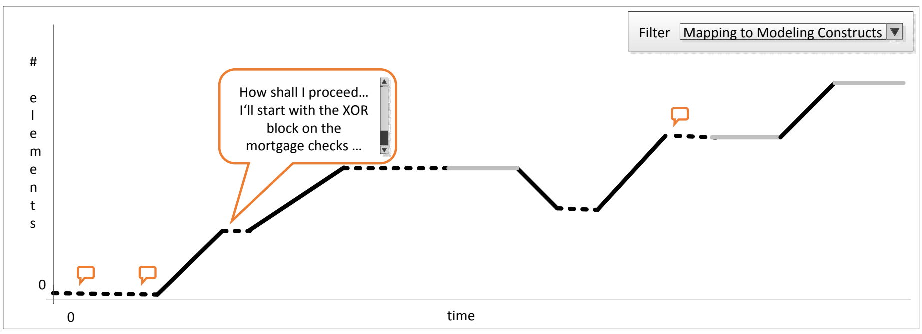

Fig. 5. Visualization of Verbal Utterances

3.2 RO_1: Identify and Assess PBPs for Process Model Creation

So far, we described how Modeling Mind intends to develop new visualizations of the PPM. Next, we describe how we approach the identification PBPs.

Identifying PBPs As starting point for identifying PBPs, the initial set outlined in Section 2.1 is used. We plan to extend this set by analyzing the modeler's interactions with the modeling environment and by considering think aloud data and data regarding the modeler's eye movements. The results of the data exploration stage are then used to propose additional PBPs resulting in an extended catalog of PBPs. We are envisioning patterns similar to the following:

Candidate Pattern 1 (CP_1) Goal Orientation Considering the visualization of think aloud protocols, one might be able to detect differences between modelers in terms of the type of thoughts uttered, e.g., modelers that are highly goal–oriented and conduct a strategic planning phase before starting with the modeling (CP_{1a}), in contrast to modelers that show less goal–oriented behavior and immediately start with modeling (CP_{1b}).

Candidate Pattern 2 (CP_2) Causes of Confusion Similarly, considering the visualization in Fig. 3, one might see different PBPs depending on whether challenges stem from difficulties in creating an internal representation of the domain to be modeled (i.e., high average fixation duration on the textual description; CP_{2a}) or from difficulties in mapping the internal representation to modeling elements (i.e., high average fixation duration on the process model; CP_{2b}).

Assessing PBPs In a next step, we investigate in how far the identified patterns are related to the quality of the resulting process models. This requires operationalizing patterns and statistically analyzing the relation to quality characteristics, e.g., using correlation analysis. As quality measures we consider *syntactic errors* (e.g., violations of the soundness property) and *semantic errors* referring to the validity (i.e., statements in the model are correct and related to the problem) and completeness (i.e., the model contains all relevant and correct statements to solve this problem) of the model. *Pragmatic quality* is typically related to the understandability of the model [41]. This includes, e.g., evaluating the process model's secondary notation. For assessing syntactic errors, we rely on existing automated techniques (e.g., [42]). For assessing semantic quality, we follow a semi–automated approach, since no fully automated solution exists [14]. We plan to utilize the ICoP framework [43] in combination with features provided by jBPT [44]. Similarly, a semi–automated approach is utilized for assessing pragmatic quality. Complementary to these approaches, we use expert assessment (e.g., in form of an iterative consensus building process [45]).

From PBPs to Modeling Styles Finally, combinations of PBPs are be combined to define modeling styles. To discover clusters of co–occurring patterns (i.e., modeling styles) we plan to use quantitative methods like correlation analysis. The identified clusters can then serve as the basis for implementing personalized modeling environments or tailored teaching materials.

3.3 RO_2: Understand Factors Determining the Occurrence of PBPs

To understand factors determining the occurrence of PBPs, we follow a two–step procedure. First, data on modeler–specific factors (cf. Section 2.2) is recorded in addition to the modeler's interactions, think aloud data, and eye movement data. Modeling tasks are planned to cover different complexity; other task–specific factors presumably affecting the occurrence of PBPs (task representation, modeling notation, and tool support) are controlled. Second, we investigate factors determining pattern occurrence. Subsequently, the expected impact of factors is described for a subset of PBPs. Respective expectations serve as starting point to be refined and extended for the newly identified PBPs. To differentiate between modeler–specific characteristics and task–specific characteristics we conduct between–modeler comparisons, between–task comparisons and within–task comparisons. Between–modeler comparisons focus on comparing modelers with different characteristics, i.e., WMC, self–regulation, domain knowledge, and process modeling expertise, who individually work on the same modeling task. Between–task comparisons, in turn, compare PBPs of the same modeler working on several tasks with different task–characteristics. For within–task comparisons, we extract slices of PPM instances and compare these slices regarding PBPs. This way, different aspects of model creation within a PPM instance can be compared. Subsequently, we present *examples* for factors that might influence the patterns described in Section 2.1.

PBP_1 *Planning* PBP_1 is related to initial comprehension duration and seems to depend on modeler–specific characteristics. In particular, locomotion ("Just doing it") and assessment ("Doing the right things") might play a role. Modelers scoring high on assessment might have longer initial comprehension phases (PBP_{1a}) when compared to modelers scoring high on locomotion (PBP_{1b}). In addition, self–regulation might play a role, i.e., modelers scoring high on self–regulation presumably have long initial comprehension phases containing strategic planning activities (PBP_{1a}). Additionally, WMC might play a moderating role since building a mental model of the task requires a high WMC (PBP_{1a}). Moreover, modelers with high modeling expertise might use pattern PBP_{1a} more frequently than less experienced modelers, since WM is used more efficiently.

PBP_2 *Detours* Regarding PBP_2, preliminary insights suggest that a modeler's WMC has a measurable impact on the number of detours taken during modeling [19]. Modelers with higher WMC are able to create the solution more efficiently, i.e., take less detours. Similar effects might occur for locomotion and assessment. For instance, high locomotion in combination with low assessment is expected to result in the highest number of detours because of modelers running into dead ends, since strategic behavior patterns are missing.

Summarized, in Modeling Mind we seek for identifying patterns in the modeler's behavior and plan to investigate the underlying factors determining the occurrence of PBPs, leading to a comprehensive understanding of the PPM.

4 Summary

This idea paper presents future research directions pursued by the Modeling Mind, intended to develop a comprehensive set of PBPs, which describe how modelers interact with the modeling environment. PBPs are explored by triangulating quantitative and qualitative research methods. For instance, we intend to analyze the modeler's interactions with the modeling environment, think aloud data, and eye movement data. Having established a set of PBPs, the research direction turns toward investigating factors determining the occurrence of PBPs. Presumably, influencing factors can be partitioned into modeler–specific factors and task–specific factors. For investigating modeler–specific factors, we intend to use established questionnaires from cognitive psychology to measure, e.g., modeling expertise, and working memory capacity. Further, the connection between process model quality in terms of syntactic, semantic, and pragmatic quality is investigated. This way, we intend to develop a model describing how modelers create process models. In this context, ignoring elicitation by assuming the existence of a complete domain description cannot be considered representative for modeling in practice. Still, the formalization of process models constitutes a sub–part of professional modeling activities. However, generalizations regarding the professional modeling community need to made with care.

By providing a theoretical model describing PBPs during the PPM and factors influencing modeling styles, we hope to facilitate the development of customized modeling environments. For instance, sketchpads in combination with a touch devise could be useful for understanding the problem, while tools for laying out process models might support the improvement of the process model's understandability. Further, a thorough understanding of the PPM enables the development of effective teaching methods helping future students to become skilled in the craft of modeling. For instance, if it turns out that specific aspects of modeling, e.g., the creation of loops, co–occur with increased mental effort, this might be an aspect teachers should specifically focus on during their instructions. This paper focuses on business process modeling, but similar investigations for other areas of conceptual modeling might be envisioned. Through this idea paper, we would like to invite researcher to join our research efforts to ultimately arrive at a comprehensive understanding of the creation of conceptual models, leading to models of higher quality.

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