Utrecht University

Master's Thesis

Business Informatics

How to learn to model

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Abstract

Business process models are used to show a visual representation of a business process. Process models are used to document and redesign business processes. Different stakeholders have to understand and comprehend these models, but it all starts with creating business process models, the process of process modeling. The process of process modeling can be seen as a problem solving task and consists of five phases. The problem understanding, method finding, modeling, reconciliation, and validation phase. In this paper, a qualitative, longitudinal experiment is conducted to investigate how the process of process modeling evolve of inexperienced modelers. With the use of Cheetah Experimental Platform (CEP) and the think aloud method, information about the model strategy can be obtained. The results show that modelers use different strategies when modeling. During the modeling sessions, fewer phases and less modeling time is needed to complete the process models.

Keywords— business process model, modeling languages, BPMN, think aloud, model strategies, Cheetah Experimental Platform (CEP)

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1 Introduction

Business process models show a description of a process. Every company consists of different types of processes and often they consist of more processes than expected [Rosemann, 2006b]. The number of processes and the complexity in organizations is increasing. With the use of models, a visual representation of the process is given with the aim that all stakeholders (management team, process owners, process analysts) have a clear overview of that process [Dumas et al., 2013].

Different techniques, tools, and modeling languages are used to formalize these processes. BPMN, Petri nets, and UML class diagrams are all examples of modeling languages used to represent business process models. Process models are used to document, redesign, and analyze business processes and form a bridge between business and IT [Rosemann, 2006a].

IT systems play a crucial role in almost every sector. Business processes are (partially) managed and supported by IT systems [van der Aalst and Stahl, 2011]. Understanding the business processes is required when developing these IT systems [Mili et al., 2010].

Business processes are crucial in every organization. There are three pillars when creating and understanding business process models.

- **Elicitation** The elicitation phase consists of obtaining all the information about the process. Obtaining process information is the starting point of documenting a business process [Pinggera, 2014] (figure 5).
- **Formalization** In the formalization phase, the business process is formalized in a process model. The information, obtained in the elicitation phase, is translated into a business process model.
- **Understanding the model** All stakeholders need to comprehend and understand process models in order to redesign and analyze the processes.

This study focuses on the process of the formalization phase, the process of process modeling. The process of process modeling can be seen as a problem solving task. When investigating the process of process modeling, a distinction is made between five phases: problem understanding, method finding, modeling, reconciliation, and validation [Pinggera et al., 2010]. In this thesis, we investigate the process of process modeling in a longitudinal modeling experiment with students.

1.1 Problem statement

As described in the introduction section, it is important that stakeholders can read and understand process models. Much research has been conducted in the domain of business model comprehension and the understandability of business process models [Petrusel et al., 2017, Zimoch et al., 2017]. But perhaps more important is the process of creating process models. This process starts with obtaining all information and translating the process into a model. When translating a process into a model, the quality of the model depends on many factors, including the strategy followed and experience in modeling.

It is possible to automate the process of process modeling. Tools that automatically generate natural language texts from process models exist [Leopold et al., 2012, Delicado Alcántara et al., 2017]. [Leopold et al., 2012] implemented a prototype to translate business process models to text. [Delicado Alcántara et al., 2017] went a step further and developed a tool that translates process models into textual descriptions and also translates a textual description of a process into a model. This tool can help in the process of process modeling but manual modeling is still important.

Some experiments in the domain of creating models have already been performed [Pinggera et al., 2010, Pinggera et al., 2011, Pinggera et al., 2012, Claes et al., 2012b, Claes et al., 2012a, Pinggera, 2014, Pinggera et al., 2015, Weber et al., 2016, Martini et al., 2016]. Subjects had to translate one or more descriptions of a process into a model in one session with the use of Cheetah Experimental Platform (CEP). CEP is a tool that supports modeling experiments. Some studies used eye tracking or think aloud to obtain additional information about the model strategies of the subjects. In all the research done before, experiments were conducted once with either subjects with no experience with modeling or subjects with (moderate) experience in modeling. An overview of these experiments is given in table 1. This study adds to these experiments by conducting an experiment four times, distributed over a course where students learn how to create process models in different modeling languages. CEP and think aloud will be used to obtain our data for this qualitative longitudinal experiment [Ericsson and Simon, 1993]. Subjects are asked to voice their thoughts when executing the experiment. CEP and think aloud are used to obtain information about the model strategies, the problem solving processes, and the learning curve during the course. This is not the first time that think aloud is used when investigating the process of process modeling. [Pinggera, 2014] used the think aloud method in his dissertation to identify the cognitive phases in the process of process modeling. The subjects were students with moderate experience in process modeling.

1.2 How do you model?

Everyone who has to deal with process models can ask themselves the question: How do I model? Students, process owners, process analysts etc. have to deal with different types of process models and model languages. Information Science students learn different types of languages to create these models. Do they use a strategy when modeling? Have they learned how to solve a problem (translating a piece of text into a process model)? We want to investigate if students explicitly use a strategy and which strategy they use. How do they translate a piece of text into a process model? In this research, we use BPMN models. An example of a process description and the corresponding model is shown below. The textual description describes the process of building a house. The BPMN model is shown in figure 1.

This process describes building a house. At the start of the process, the available amount of money to build the house must be determined. After that, an architect is selected and an orientation talk is held with the architect. The requirements of the house, location of the house and other information about building a house are discussed. These activities take parallel to each other. After the talk with the architect, it is determined whether or not the architect is hired for the project. When the architect is not hired, a new architect is chosen. When the architect is hired, the architect makes a sketch of the house. When the sketch is approved, the architects makes a design. If the sketch is not approved, a new sketch is made by the architect. After that, there must be a building permit for building the house legally. It is possible that the land is already in the possession of the owner or that a lot has to be bought. If the land is already in the possession of the owner, the zoning plan is checked and the building permit can be requested. If the lot still needs to be purchased, a self-build lot is purchased and the building permit is requested. For requesting the building permit, pictures of the lot, drawings of the building, and technical information must be included. If the building permit is not approved, the request process for a building permit starts again. When the building permit is approved, the preparation for building the house can begin. First, the architect prepares a complete set of documents for the constructor. Second, a contractor is selected for building the house. This process continues until a suitable contractor is found. After selecting a contractor, the contractor makes a contract. At the same time, a timeline is made for the construction. Last, the contract is signed and the process ends.

Figure 1: *BPMN model example*

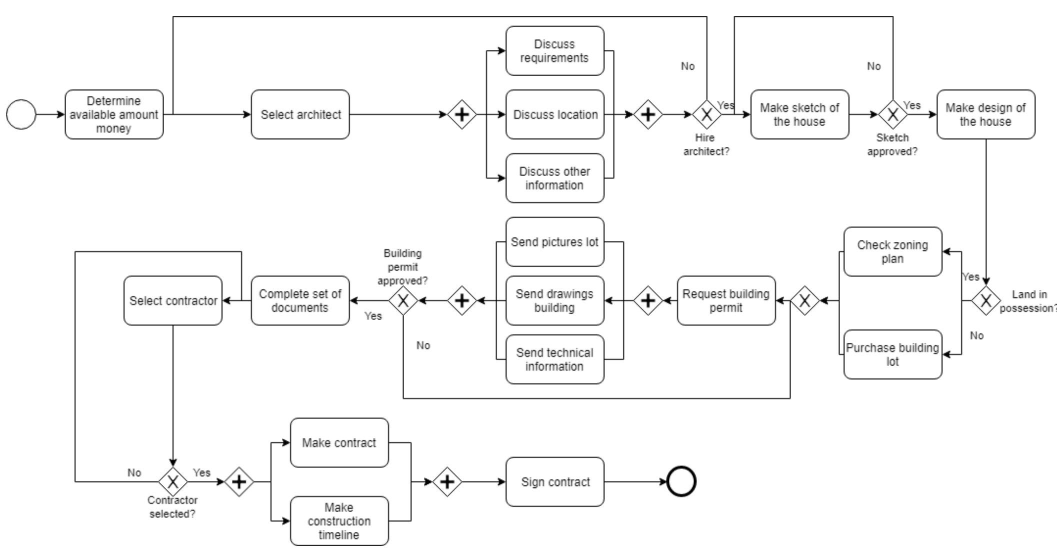


Table 1: Research done before

Article	Student/ Expert	# Subjects	Beginner/ Moderate/ Expert	# Models	# Activities	CEP	Eye tracking	Think aloud	Longitudinal
[Pinggera et al., 2010]	Master students	83	Moderate	1	24	X			
[Pinggera et al., 2011]	Master students	26	Moderate	1	24	X			
[Pinggera et al., 2015]	Students	115	Moderate	2	9 & 12	X			
[Claes et al., 2012b]	Students	103	Moderate	1	12	X			
[Pinggera et al., 2012]	Students	25	Moderate	1	19	X	X		
[Weber et al., 2016]	Students (30 computer science, 90 psychology)	120	Beginner/ Moderate	3 Simple (30 psychology)	12	X	X		
				Medium (30 psychology)	19				
				Complex (30 psychology, 30 computer science	27				
[Pinggera et al., 2014]	Students	6	Moderate	1	11	X		X	
[Pinggera et al., 2014]	Students	25	Moderate	1	19	X	X		
[Pinggera et al., 2014]	Students	120	Moderate	1	24	X			
[Martini et al., 2016]	Students (30 computer science, 30 psychology)	60	Beginner/ Moderate	1	16	X			

1.3 Thesis outline

The remainder of this project proposal is structured as follows. Chapter 2 defines the research approach of this research. The research questions, research methods, and hypotheses are defined. Information about business process modeling is given in chapter 3. In chapter 4, different strategies to solve a problem are explained which will answer SQ1. Chapter 5 describes how phases in modeling can be measured to answer SQ2. The process of process modeling and research done before is set forth in chapter 6. Chapter 7 describes different types of factors that affect modeling (SQ3). We have to take these factors into account when designing our experiment. The experiment design is defined in chapter 8. The results are divided into results per subject and model (chapter 9), and results per phase (chapter 10). Finally, the conclusions and suggestions for future research are defined in chapter 11.

2 Research approach

This chapter describes the research approach for this study. In section 2.1, the research questions are defined. In section 2.2, the research methods used for this research are described. Section 2.3 defines the hypotheses for SQ4, SQ4.1, SQ4.2, SQ4.3, and SQ4.4.

2.1 Research questions

In this study, we want to investigate the learning curve in process model strategies of inexperienced modelers and whether these strategies can be identified with the help of CEP and think aloud. Because we conduct the experiment four times with the same subjects, we want to investigate the learning effect and whether modeling strategies evolve. The inexperienced modelers are students who are all following the course Information Systems where they learn how to model. The main research question of this study is:

What is the learning curve in process modeling strategies of inexperienced modelers?

The main research question can be divided in multiple sub research questions. First, we will conduct a literature study to find more information about strategies in problem solving tasks. In particular, translating a description of a process into a process model.

SQ1: What are possible strategies according to the literature when translating a description of a process into a process model?

Translating an informal description of a process into a process model can be seen as a problem solving task. How do you solve such a problem? Which strategies would you use when solving this problem and which phases are needed? To answer these questions, a literature study is conducted. The findings of this literature study are set forth in chapter 4.

When there is more information about the possible strategies when solving a problem, we have to find out how to measure the different phases in the process of process modeling. The second sub research question can be formulated as follows:

SQ2: How can different phases in modeling be measured?

Different factors affect the process of process modeling which we have to take into account. These factors can be divided into task specific factors and modeler specific factors. The third research question can be formulated as follows:

SQ3: Which task specific factors and modeler specific factors affect the process of process modeling?

Since we conduct the experiment four times with the same subjects, we can analyze the changes in modeling strategy and the quality of the created models. Does the strategy change over time? What exactly changed after each session? This leads to the fourth research question:

SQ4: How does the process of process modeling evolve during a longitudinal experiment where subjects have to translate a description of a process into a process model?

It is possible that the strategy remains the same but that the duration of the different phases change or that the sequence of phases will change. First, we have to investigate which strategies subjects use when translating a description of a process into a process model. The fourth research question can be divided into multiple sub research questions.

SQ4.1: Which modeling strategies are used when translating a description of a process into a process model?

SQ4.2: Does the strategy change during the sessions?

SQ4.3: Does the number of modeling phases change during the sessions?

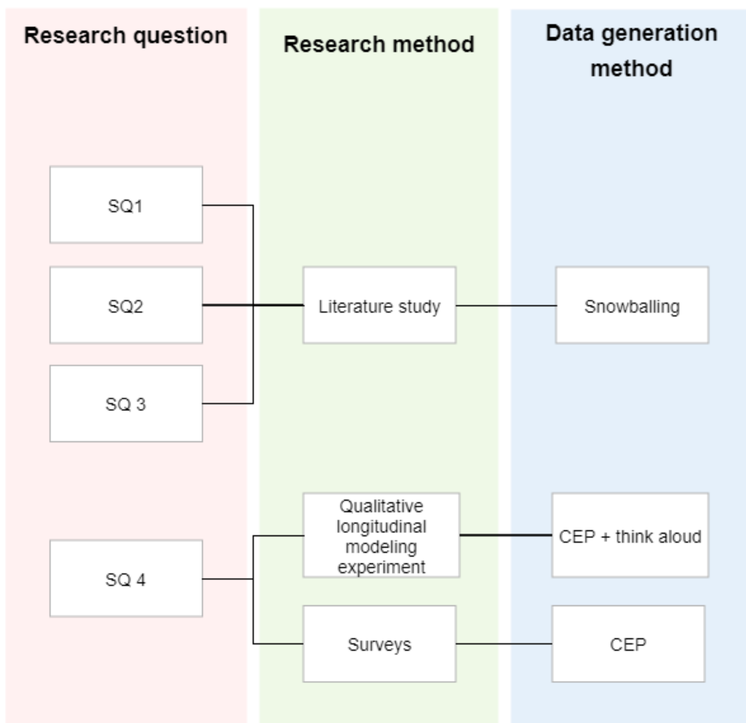
SQ4.4: Does the duration of modeling phases change during the sessions?

In the next section, the research method of this experiment is explained.

2.2 Research methods

Different research methods are used to answer the research questions of this research. Figure 2 gives an overview of the research and data generation methods used per research question. In the next sections, the different research methods and data generation methods are explained in more detail.

Figure 2: *Research overview*



2.2.1 Literature study

This research started with an exploratory literature study to obtain some general information about the process of process modeling and previous studies done so far. This helped to shape this research in more detail. The exploratory literature study resulted in two papers that are used as a starting point for the snowballing method.

- Pinggera, Soffer, Fahland, Weidlich, Zugal, Weber, Reijers, Mendling (2015), Styles in business process modeling: an exploration and a model. [Pinggera et al., 2015]
- Petrusel, Mendling, Reijers (2017), How visual cognition influences process model comprehension. [Petrusel et al., 2017]

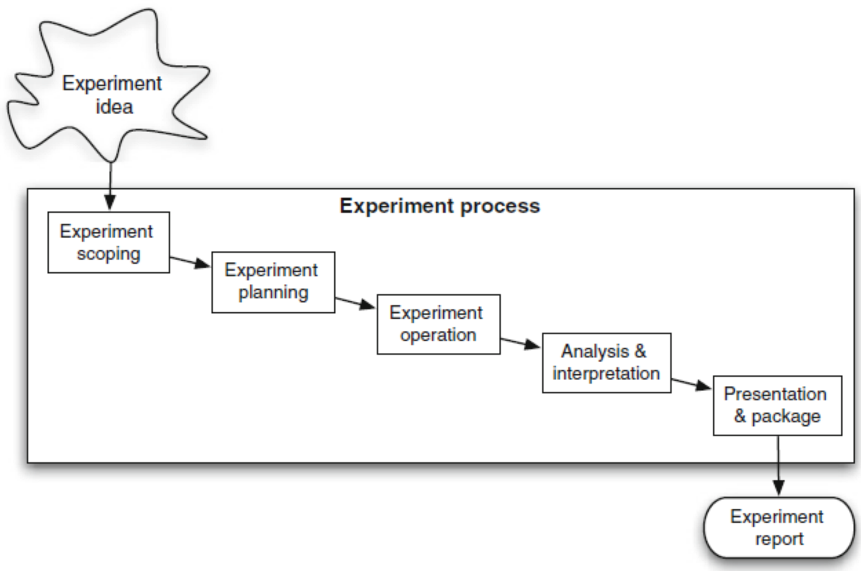
In addition to the snowballing method, 'Google', 'Google Scholar', 'dblp.org', 'Scopus', and the Library catalogue of Utrecht University were used to find more relevant papers. Examples of search terms: 'business process modeling', 'process model comprehension', 'think aloud', information systems', 'BPMN modeling', 'cognitive load' etc.

After the exploratory literature study, the research questions are defined (section 2.1). To answer SQ1, SQ2, and SQ3, a more in-depth literature study on the relevant areas is executed. We used the unstructured snowballing method again. First, more information is needed about the possible strategies and phases when solving a problem. In this case: translating a description of a process into a process model. After that, a literature study to answer SQ2 and SQ3 is conducted.

2.2.2 Experiment

The main part of this research is planning and conducting the experiment. In order to answer SQ4, we will conduct a qualitative longitudinal experiment using CEP and think aloud. The experiment process according to [Wohlin et al., 2012] is used to design, execute, and analyze this experiment (figure 3).

Figure 3: *Process experiment [Wohlin et al., 2012]*



In the experiment scoping phase, the problems, objectives, and goals of this experiment are determined. The experimental planning phase consists of determining the experimental design and defining the hypotheses. The experimental design consists of determining the variables, subjects, objects, instrumentation, choice of design type, and threats to validity. In the experiment operation phase, the experiment is conducted and data is collected. The collected data is analyzed in the analysis and interpretation phase. The conclusions of the experiment are reported in the presentation and package phase.

Qualitative This research is a qualitative research. A small group of subjects is used to analyze evolution in modeling. This research is not about quantity but rather to gather information about modeling strategies of a small group of subjects. The process of process modeling can be observed and analyzed afterwards because all interactions with the modeling environment and verbal utterances are recorded.

Longitudinal This experiment is conducted over a period of time with the same subjects. This is called a longitudinal study. A longitudinal study is used to investigate something that changes over time. For this study: the evolution in process modeling strategies. The experiment is conducted with students who are following the course Information Systems. The duration of this course is ten weeks and the experiment is conducted four times.

Two data generation methods for research question 4 are used: Cheetah Experimental Platform (CEP) and the think aloud method. CEP is a tool which logs all modeling interactions, store answers of the surveys, and makes it possible to analyze the modeling interactions. More information about CEP is given in section 5.1. Think aloud is used to obtain additional information about the different modeling phases (section 5.2).

2.2.3 Survey

Subjects must complete a survey at the beginning and at the end of each session. The surveys consist of open, closed, and 5 point Likert-scale questions and have an explanatory objective [Wohlin et al., 2012]. Questions about the confidence rate of modeling business processes are asked beforehand. Questions about the perceived difficulty are asked afterwards. It is possible to insert these surveys in CEP. CEP stores the answers on a local hard drive. The surveys are shown in the appendices.

2.3 Hypotheses

For SQ4, SQ4.1, SQ4.2, SQ4.3, and SQ 4.4 the H0 and the H1 hypotheses are defined in the next sections.

2.3.1 Hypothesis SQ4

H0: There are no changes in strategy when there is more experience in translating a description of a process into a process model.
H1: There are changes in strategy when there is more experience in translating a description of a process into a process model.

The null hypothesis of SQ4 states that the strategy for translating a description of a process into a process model remains the same when there is more experience in process modeling. This means that the same modeling phases are used in each session. The alternative hypothesis states that the strategy would change when there is more experience in modeling. More experience could lead to a different sequence of phases, duration of phases, and the overall time spent on the task can change.

2.3.2 Hypothesis SQ4.1

H0: It is not possible to distinct different modeling strategies in process modeling.
H1: It is possible to distinct different modeling strategies in process modeling.

Is it the case that all subjects use the same strategy when modeling a process? What are the different approaches when translating a description of a process? The null hypothesis of SQ4.1 states that it is not possible to distinct different modeling strategies. Personal preferences can, for example, influence the used strategy. The alternative hypothesis states that it is possible to distinct different modeling strategies in process modeling.

2.3.3 Hypothesis SQ4.2

H0: The strategy to create a process model will not change during the sessions.
H1: The strategy to create a process model will change during the sessions.

This research question investigates the differences in modeling strategies during the sessions. Are the modeling strategies of the subjects the same in every session? The null hypothesis of SQ4.2 states that the strategy to create a process model will not change during the sessions. The alternative hypothesis states that the strategy to create a process model will change during the sessions.

2.3.4 Hypothesis SQ4.3

H0: The number of modeling phases does not change during the sessions.
H1: The number of phases changes during the sessions.

Does the number of phases change when modelers have more experience in process modeling? The null hypothesis states that the number of modeling phases does not change during the sessions. The alternative hypothesis states that the number of phases changes during the sessions.

2.3.5 Hypothesis SQ4.4

H0: The duration of modeling phases does not change during the sessions.
H1: The duration of modeling phases changes during the sessions.

Does the duration spent in the different modeling phases change during the sessions? The null hypothesis states that the duration does not change during the sessions. The alternative hypothesis states that the duration of modeling phases changes during the sessions.

3 Business process modeling

To understand the basic principles of business process models, information systems, and modeling languages, some background information is given in this chapter. In section 3.1, we will explain the role of business processes and the connection with information systems. Different types of modeling languages exist to formalize business processes. These modeling languages are explained in section 3.2. A lot of research is done in the domain of business process model comprehension. Which factors influence business process model comprehension is described in section 3.3. To analyze the quality of business process models, different types of quality frameworks can be used. These quality frameworks are explained in section 3.4.

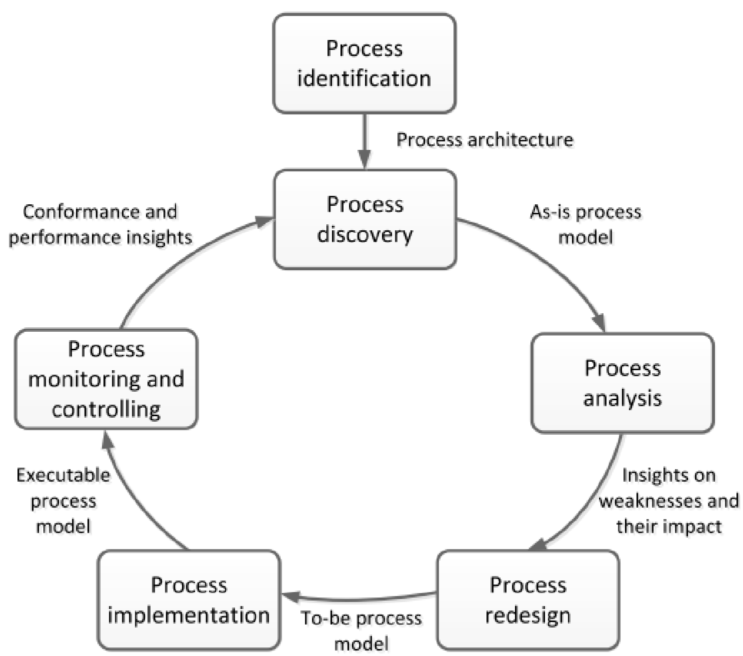
3.1 Business processes

As stated in the introduction and problem statement section, every organization consists of different types of business processes. When an organization delivers a service or product to a customer, it is called a business process. Think for example of order fulfillment, mortgage request, complaint handling, etc. Business processes are managed and supported by information systems [van der Aalst and Stahl, 2011]. A business process consists of events, activities, decision points, and one or more outcomes [Dumas et al., 2013]. [Dumas et al., 2013] give the following definition of a business process:

"A business process is a collection of inter-related events, activities and decision points that involve a number of actors and objects, and that collectively lead to an outcome that is of value to at least one customer".

Events are things that happen atomically. An event can be the starting point of one or more activities. A decision point is a point when a decision is made in the process. Actors are for example organizations or software systems. There are two types of objects: physical objects, and immaterial objects. In the end, every process leads to one or more outcomes.

Figure 4: *BPM lifecycle [Dumas et al., 2013]*

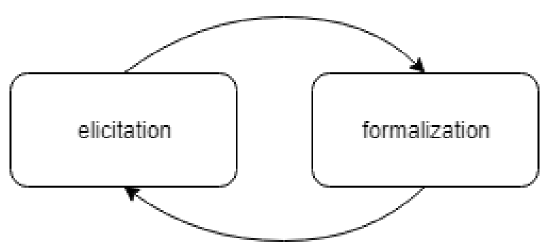


The number of processes and the complexity of processes in organizations is increasing. Different techniques, tools, and modeling languages are used to formalize these processes. Modeling business processes is nowadays a standard activity in many organizations [van Hee et al., 2013]. With diagrams, ambiguity and misinterpretation of the description of the process are reduced [Dumas et al., 2013]. Modeling a business process is also a way to understand the relevant information systems [van Hee et al., 2013].

Processes can change over time, documented processes are usually outdated, and some processes are not even described at all. To understand, control, manage, execute, analyze, redesign, and optimize all business processes, companies are using Business Process Management (BPM). With BPM, organizations can formalize processes which are of good quality, consistent, and cost-efficient [Vom Brocke et al., 2010]. Despite all the advantages, organizations have difficulties with implementing BPM in the right way [Vom Brocke et al., 2010, Malinova and Mendling, 2012]. Therefore, the life-cycle of business process management is defined as the BPM life-cycle in figure 4 [Dumas et al., 2013]. The BPM life-cycle starts with the identification of a process. What type of process is it? What are the different steps in the process? This will result in an overall view of a process. In the process discovery phase, the process is described in more detail. Here, the business's current process is identified. There are three different approaches to identify the current state of the process. You can use available documents to obtain insights into the process. Another way is the use of different types of tools, for example process mining. The third approach is getting information from employees. Interviews, questionnaires, and role games can be used to gain insights. The discovery of the process will result in a detailed description of the as-is process model. After that, the analysis of the process will take place which will give insights on weaknesses and their impact on the process. The outcome of this phase is a collection of issues. The goal of process redesign is to solve issues which are collected in the previous phase. This will result in a to-be process model. After that, the implementation of the process will take place with all the changes implemented. This leads to an executable process model. Finally, the process is monitored and checked.

[Pinggera, 2014] used a simplified version of the process development life cycle (figure 5) consisting of an elicitation and a formalization phase. The information required for formalizing the process is obtained in the elicitation phase. Good communication between stakeholders and experts is needed to get a complete overview of the process. In the formalization phase, the actual process of process modeling is taking place. Different tools and modeling languages are used to manage business processes. In the next section, these different modeling languages are set forth.

Figure 5: *Process lifecycle*



3.1.1 Information systems

As said in previous sections, business processes are managed and supported by information systems [van der Aalst and Stahl, 2011] and form a bridge between business and IT [Rosemann, 2006a]. In our daily lives, we constantly use information systems. Business processes are partly or completely supported by information systems. [van der Aalst and Stahl, 2011] give the following definition of an information system:

"An information system is a software system to capture, transmit, store, retrieve, manipulate, or display information, thereby supporting people, organizations, or other software systems".

Business process models are not only important for the processes itself but also for the development of information systems that supports business processes. It is possible that an information system supports a part of the business process. In the process of order fulfillment, information systems can be used to check stock availability, receive payments, and archive the order. In the process of a mortgage request, information systems can be used to store the mortgage requests and calculate the mortgage request. An information system may support the whole business process from beginning to end. The overlap of business process models and information systems is increasing due to the development of information systems [van der Aalst and Stahl, 2011].

3.2 Modeling languages

There exist a lot of different modeling languages to formalize business process models. Examples include EPC, Petri Net, BPMN, and eGantt. Modelers are uncertain what the difference between those modeling languages is and when to use which language. [Kopp et al., 2009]. This section explains some findings in the domain of modeling languages in general. In the course Information Systems, that is followed by our subjects, two types of modeling languages are taught: Petri net, and BPMN. These modeling languages are explained in more detail in section 3.2.1 and section 3.2.2.

It is difficult to compare all existing modeling languages. There are different theories about how to compare modeling languages and how to categorize them in literature. [Söderström et al., 2002] suggest a framework to make it possible to compare business modeling languages. The framework is validated by comparing three modeling languages: Business Modeling Language (BML), EPC, and UML state diagrams. The framework provides a basis for selecting the right process modeling language, and to compare different types of process modeling languages. [List and Korherr, 2006] suggest a meta-model which focuses on conceptual business process models. UML, BPMN, EPC, and Petri net are all examples of conceptual business process languages. With this meta-model, it is possible to evaluate and compare these modeling languages. It consists of four perspectives: organizational, functional, behavioural, and informational.

[Zimoch et al., 2017] investigate the comprehension of four different modeling languages: EPC, Petri net, BPMN, and eGantt. The results show that when the complexity of the models increase, the comprehension performance decrease for all modeling languages. A more detaileds description of this study is given in section 3.3. [Recker and Dreiling, 2007] investigate the difference between EPC and BPMN. They taught subjects how to create EPC models but the subjects were not taught about how to create BPMN models. There was no difference in learning outcomes between EPC and BPMN models.

Various attempts have been made to categorize process modeling languages and to compare modeling languages. Participants of this experiment learn two types of modeling languages: BPMN and Petri net. BPMN and Petri net are both conceptual models. In addition to these categorizations, BPMN models are activity-based and Petri nets are state-based. More information about these modeling languages is given in the following sections.

3.2.1 Petri net

Petri net is a state-based modeling language, used to formalize business processes [van der Aalst and Stahl, 2011]. Petri nets consist of places, transitions, and tokens. In a Petri net, places are represented by circles and transitions are represented by rectangles. Places indicate the components of a state. Transitions indicate how a state can change. Arcs can connect places and transitions. Connections between two places or two transitions are not possible. Places may contain one or more tokens which are represented as black dots. Tokens determine the state of the Petri net. When a transition fires, the number of tokens can change and the Petri net moves to another state. To summarize:

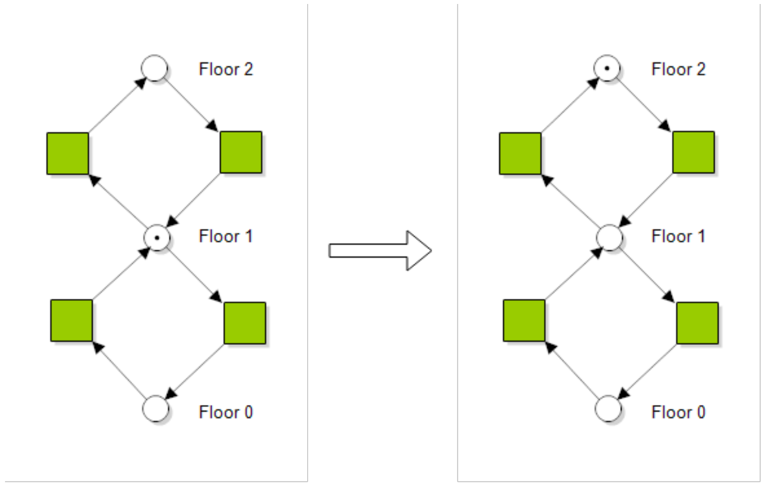
$$P \text{ is a finite set of places}$$
$$T \text{ is a finite set of transitions}$$
$$F \subseteq (P \times T) \cup (T \times P) \text{ is a flow relation}$$

Figure 6 shows a simple example of a Petri net which represents an elevator. Each floor is modeled as a place. The transitions represent the movements of the elevator. Suppose that the elevator is on the first floor, and contains a token. The elevator can either go up to the second floor or go down to the ground floor. When the elevator goes up to the second floor, the Petri net moves to another state and the token will be moved to 'floor 2'.

3.2.2 BPMN

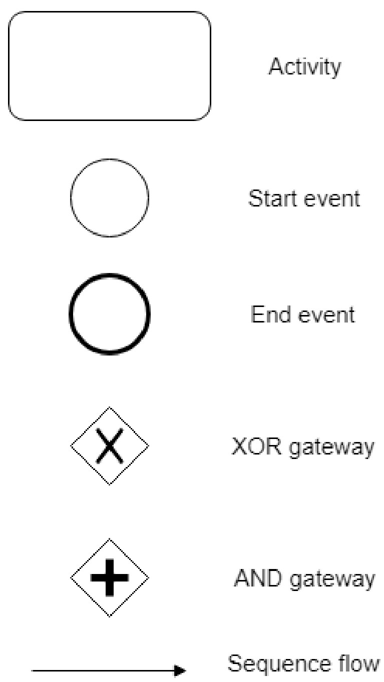
BPMN is developed by the Object Management Group (OMG) and is the most commonly used model language. BPMN models are activity-based and consist of a lot of symbols. These can be complex, therefore we use a subset of the

Figure 6: *Petri net*



BPMN model. In the course Information Systems only a subset of BPMN is learned as well. Furthermore, a subset of the model is used in real life too. [Zur Muehlen and Recker, 2013] analyzed 120 BPMN models and concluded that only 20% of the symbols are regularly used. The elements of the BPMN that were used in this experiment can be found in figure 7. The goal of the developers of BPMN is a modeling language that is understandable for all stakeholders [bpm, 2019].

Figure 7: *BPMN elements*



Every BPMN model begins with a start-event represented by a circle, which triggers a new process instance. This is the first step in the business process. The activities are rounded rectangles with a name for each activity. For example, "Confirm order". Every activity name starts with an action verb followed by a noun. Two types of gateways are used: the XOR gateway and the AND gateway. A gateway controls the divergence (split gateway) and convergence (join gateway) of flows in a business process model. A split gateway has one incoming sequence flow and multiple outgoing sequence flows. A join gateway has multiple incoming sequence flows and one outgoing sequence flow [Dumas et al., 2013]. An XOR-split gateway takes one outgoing branch depending on the condition and splits the flow in two or more exclusive paths. The XOR-join gateway proceeds when one of the incoming branches has completed (figure 8).

Figure 8: *XOR-split and XOR-join gateway*

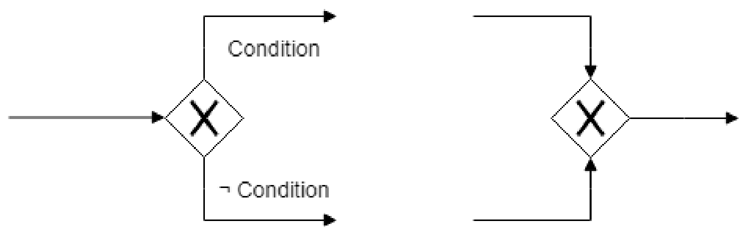
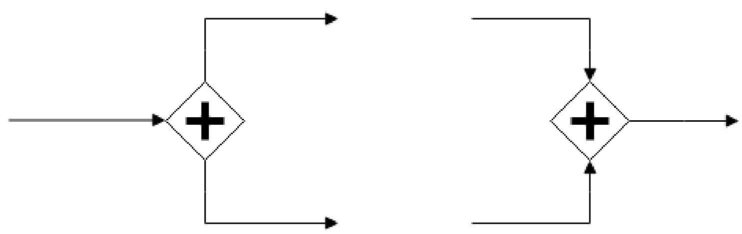


Figure 9: *AND-split and AND-join gateway*



The AND gateway is used to represent two or more concurrent activities and does not depend on a condition. The AND-split gateway executes all outgoing branches. The AND-join gateway proceeds when all of the incoming branches are completed (figure 9). Every process ends with an end event, which signals that a process instance is completed. A sequence flow is represented by an arc and connects the activities and events. An example of a BPMN model is shown in figure 1.

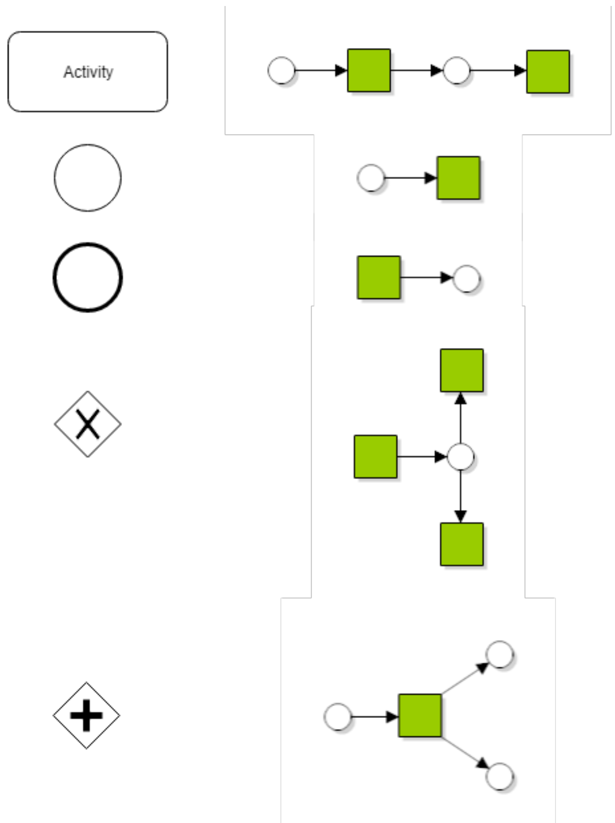
3.2.3 From Petri net to BPMN

Although Petri net models and BPMN models are not very similar at first sight, they have more similarities than expected. A Petri net model is a state-based modeling language, whereas a BPMN model an activity-based modeling language. A subset of BPMN elements can be translated into Petri net models and vice-versa. An activity in a BPMN model shows that you are doing something that takes time. In a Petri net, this is represented by a place, represented by circles. A transition in a Petri net indicates how a state can change. Figure 10 shows the mapping of BPMN elements onto Petri net elements. An activity in a BPMN model can be translated into for example: I could start (place), I am going to start (transition), I started (place), I stop (transition).

3.3 Business process model comprehension

As mentioned previously, it is essential that different stakeholders can read and understand business process models. Only if all stakeholders comprehend business process models, good communication about these models is possible. Good communication is needed to understand, control, manage, redesign etc. process models. Even though business process model comprehension and understandability is not part of this research, it is important for the overall concept of business process modeling. A lot of research is done in the domain of model comprehension and understandability. Factors that influence the comprehension of process models are explained in this section on the basis of a few studies.

Figure 10: *From BPMN to Petri net*



Complexity level model The complexity level of the model plays a crucial role in understanding the process model. [Zimoch et al., 2017] used three levels of difficulty of the process models and used eye tracking for measuring the results. The results show that when the complexity of the model increases, the comprehension performance decreases. Also, the number of fixations when focusing on XOR gateways is higher compared to AND gateways, which indicates that XOR gateways are harder to understand compared to AND gateways.

Structure/layout model The structure and layout of the model might also influence process model comprehension. The results of the comprehension tasks are better when there is an explicit start and end event in a model [Zimoch et al., 2017]. [Gschwind et al., 2014] developed an algorithm that helps modelers with creating business process models with a proper layout.

Modeling language The type of modeling language might influence the process model comprehension. However, [Zimoch et al., 2017] did research for four types of modeling languages (EPC, Petri net, BPMN, and eGantt). The results show that when the complexity level increase, the comprehension performance decrease for all types of modeling languages.

Process knowledge When somebody is more familiar with a particular process, the cognitive load in working memory is lower, and therefore easier to understand the model [Zimoch et al., 2017].

Personal factors Different types of personal factors are investigated by [Reijers and Mendling, 2011]. Personal factors are theoretical knowledge of process modeling, educational background, and practical experience. The results show that better personal factors will lead to a better understanding of the process model.

Some of these factors also affect the process of process modeling. These factors and how they affect the process of process modeling are explained in chapter 7.

3.4 Quality frameworks of process models

Different types of frameworks exist to determine the quality of a process model, focusing on the created model. In this research, we will analyze the quality of the created models on a high level. We are more interested in the process of creating a process model than the quality of the created model. How do you determine the quality of a process model?

There are three dimensions of quality of process models: syntactic quality, semantic quality, and pragmatic quality [Lindland et al., 1994]. Syntactic and semantic quality relates to the correct use of the modeling language. Are the BPMN elements used the right way? Is the model correct? Do all the names of the activities start with a verb? Is the model complete? Pragmatic quality relates to the understandability of the created process model. All stakeholders must understand the model. An example of a pragmatic quality is the layout of the model. When a model has a proper layout, the model is easier to read and understand [Zimoch et al., 2017].

Besides the three quality dimensions, there are different types of frameworks for evaluating the quality of process models. The SEQUAL framework [Krogstie et al., 2006] is based on the three dimensions according to [Lindland et al., 1994] and semiotic theory. The Guidelines of Modeling (GoM) framework [Becker et al., 2000] aims to improve the quality of the created process model as well as the quality of the process of process modeling. With the GoM framework, they want to develop specific design recommendations. The GoM framework consists of six guidelines: correctness, relevance, economic efficiency, clarity, comparability, and systematic design.

Because of the abstraction of the SEQUAL and GoM framework, [Mendling et al., 2010] designed a new framework, the seven process modeling guidelines (7PMG). These guidelines are also applicable for moderate modelers and not only for expert modelers. The 7PMG helps modelers to create a process model from scratch as well as improving already created process models [Mendling et al., 2010]. The 7PMG are:

1. Use as few elements in the model as possible.
2. Minimize the routing paths per element.
3. Use one start and one end event.
4. Model as structured as possible.
5. Avoid OR routing elements. We will not use the OR gateway in our experiment.
6. Use verb-object activity labels.
7. Decompose the model if it has more than 50 elements.

As described above, different quality frameworks exist for evaluating process models. Since we analyze the quality of the created process models on a high level we will use the 7PMG to determine the quality of the created business process models.

3.5 Conclusion

Business processes exist in every organization, and often, they are formalized in multiple process models. Organizations use Business Process Management to understand, control, formalize, and manage their business processes. The Business Process Management life cycle is used to create and manage business processes. Furthermore, business processes are completely or partly supported by information systems. Business processes can be formalized in different types of modeling languages. The subjects, used in this research, learn how to create BPMN and Petri net models. BPMN is an activity-based language whereas Petri net is a state-based modeling language. After formalizing the business processes, the stakeholders must understand and comprehend the models. Different types of factors such as the complexity level of the model and the modeling language can affect business process model comprehension. To evaluate the created models, different frameworks exist to determine the quality. This research focuses on the formalization of a business process, the process of process modeling. The remainder of this research will focus on the process of process modeling of BPMN models.

4 Problem solving

This chapter aims to answer SQ1

SQ1 What are possible strategies according to the literature when translating a description of a process into a process model?

The process of process modeling can be seen as solving a problem: translating a description of a process into a process model. As seen in the previous sections, different types of factors influence business process model comprehension. Different factors influence the process of process modeling as well. Cognitive load and memory has a significant influence on the strategy used to solve the problem. How memory affects the used strategy is explained in section 4.1. Process modeling can be seen as a wicked problem (section 4.2). The five phases of process modeling are explained in section 4.3. [Tang, 2011] discussed design reasoning failures and techniques to improve design reasoning (section 4.4). Similarities and differences between novel and experts in various problem solving tasks are explained in section 4.5.

4.1 Cognitive load

An important factor that influences the process of process modeling is the limitation of the human mind, in particular memory. Memory is the capacity to store and retrieve information [Friedenberg and Silverman, 2012]. Your memory helps you to deal with new situations because you have learned from somewhat similar situations in the past.

Storage and retrieval of information is dependent on sensory memory, working memory (short-term memory), and long-term memory and affects the cognitive load. The cognitive load theory describes how memory is affected when solving a problem [Sweller et al., 1998]. Some interesting factors of memory are the duration of memory, storage, and the capacity of memory. Sensory memory, working memory, and long-term memory are explained in more detail in the next sections.

4.1.1 Sensory memory

Your sensory memory holds sensory information for a very short period of time for each sense [Friedenberg and Silverman, 2012]. Sensory memory has a very short duration but on the other hand, a large capacity. Information is stored automatically without the need of being aware of it. The purpose of sensory memory is to hold information of the stimulus for a very short period of time, but long enough to recognize the stimulus. Visual sensory memory, for example, holds information of the visual representation for 250 milliseconds [Friedenberg and Silverman, 2012]. The task of sensory memory is to decide which information is important enough to store in working memory.

When reading a textual description of a process, the visual sensory memory is active and decides which part of the text is transferred to your working memory.

4.1.2 Working memory

In working memory, information is stored for a longer period of time compared to sensory memory but it has a limited capacity. Working memory plays an important role when solving a problem. Information is stored for a short period of time in working memory [Friedenberg and Silverman, 2012]. Think of remembering a phone number when there is no possibility to write it down. What people do to remember the phone number is repeating the phone number aloud. In this way, the phone number is stored in your short term memory [Friedenberg and Silverman, 2012].

Only 7 ± 2 items can be stored in working memory [Miller, 1956]. Have a quick look at the following sequence of letters: G-F-O-W-R-X-D-L-P. How many items can you remember after a short period of time of looking at it? 9 items are probably too many to store in your working memory.

In our research, participants have to solve a problem: translating a description of a process into a process model. Participants have to read a textual description of a process. Because only a small number of items can be stored in working memory, the textual description is too long to store in working memory in one time.

4.1.3 Long-term memory

Long-term memory information is stored for a longer period of time, even for months or years. Think of memories of your holidays a few years ago, memories of your childhood, or what you ate last week. These types of memories are declarative memories. Knowing how to walk or ride a bike are procedural memories. People are often not conscious of their long term memory [Sweller et al., 1998].

Working memory and long term memory are strongly related to each other. After information is stored in working memory, relevant information is encoded in your long term memory. Information can be retrieved from your long term memory into your working memory. How is the information stored in long-term memory? According to some theories, information is stored in the form of schemas [Sweller et al., 1998]. This will help to organize information in long term memory.

When translating a description of a process into a BPMN model, knowledge about the modeling language and how to use an AND or XOR gate is required [Pinggera, 2014]. When rules of how to use an AND or XOR gate are stored in schemas in long term memory, it is easier to create new models from a textual description. The use of gates and other elements of BPMN is automated and therefore easier to create new models. It also will reduce working memory [Sweller et al., 1998].

4.2 Wicked problem

A wicked problem is defined for social policy problems [Rittel and Webber, 1973]. [Coyne, 2005] stated that design tasks can also be seen as a wicked problem. A wicked problem consists of ten rules.

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rules.
3. Solutions to wicked problems are not true or false, but good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a one-shot operation, because there is no opportunity to learn by trial and error.
6. Wicked problems do not have an enumerable set of potential solutions.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. the existence of a discrepancy representing a wicked problem can be explained in numerous ways.
10. The wicked problem solver has no right to be wrong.

[Coyne, 2005] explained that design tasks are diminished wicked problems. The process of process modeling confirms to rule 1, 2, 3, 4, 6, 7, 8, 9 and 10.

4.3 Five phases of process modeling

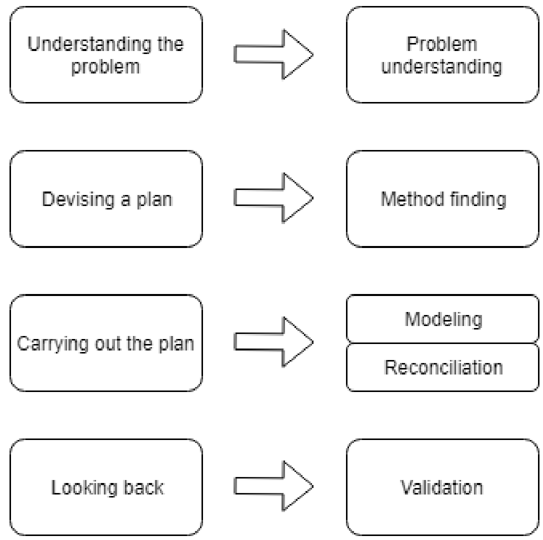
For every problem is a solution but you have to discover the solution to solve the problem. If you find the solution, you may experience the joy of your discovery [Polya, 1957]. According to [Polya, 1957], the process of problem solving starts with understanding the problem. Do you understand the problem? Then you have to devise a plan. Are you familiar with the problem or do you know a related problem? If there are problems with devising a plan, it is always possible to split the problem into smaller parts which make the entire problem more accessible. Third, you have to carry out the plan. After carrying out the plan, you have to look back to check your results. If you checked your result and you are satisfied with the solution, the problem is solved.

It is possible to translate the process of problem solving of [Polya, 1957] into five phases in process modeling used in previous studies (figure 11) [Pinggera, 2014, Weber et al., 2016, Pinggera et al., 2012]. These five phases are based on cognitive activities in computer programming.

The five phases are: problem understanding, method finding, modeling, reconciliation, and validation.

Problem understanding During the problem understanding phase, modelers read the description of the process and try to understand the textual description. Modelers make a mental representation of the process in order to create the process model. Working memory plays a crucial role in the problem understanding phase. Only a small number of items can temporarily be stored in working memory [Friedenberg and Silverman, 2012]. Because of the small

Figure 11: *Problem solving steps*



number of items that can be stored in working memory, the modeler can not store the whole process description at once [Pinggera, 2014]. The problem is split into smaller parts to make it more accessible.

Method finding The method finding phase is used to find a method to translate the mental representation into a process model. With the subset of BPMN elements used in this experiment, modelers need to find a way to translate the informal description of a process into a process model. After the method finding phase, creating the model can start.

Modeling The modeling phase is where actual modeling takes place. The mental representation is translated into a model. Creating elements, deleting elements, reconnecting edges, and adding/deleting edges are actions of the modeling phase. As said in the problem understanding phase, working memory determines how much BPMN elements can be created before the modeler has to go back to the problem understanding phase. BPMN elements used in this experiment are activities, start event, end event, XOR gateways, AND gateways, and sequence flows.

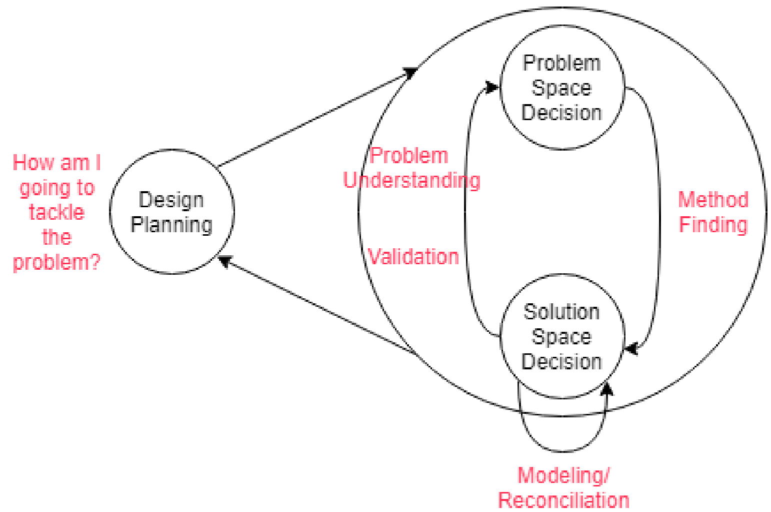
Reconciliation The reconciliation phase is used to improve the created model. Moving elements, renaming elements, laying out edges, and updating edges are actions that are part of the reconciliation phase. For example, Modelers can decide to move elements to create a better layout [Gschwind et al., 2014] or to make the model compact to reduce the need for scrolling. Also, Modelers can decide to rename elements to reduce ambiguity or to make the model more coherent.

Validation Like [Polya, 1957] said, after carrying out the task you have to look back to check your results. This is what happens in the validation phase. Modelers check their created models. They compare their mental representation of the model with the actual created model [Pinggera, 2014] and check the created model for syntactic and semantic quality issues.

4.4 Design reasoning

As discussed in the previous sections, the process of process modeling consists of five phases and the limitations of the human mind and cognitive load play a crucial role. How do modelers decide which phase is the next one? How am I going to tackle the problem? How do I make logical design decisions? [Tang, 2011] discussed design reasoning failures and techniques to improve design reasoning in software design. As we have seen before, software design is related to process modeling. The skills of the modeler are important but expert modelers can still make bad design decisions. [Tang, 2011] suggest a problem structuring reasoning technique consisting of design planning and problem-solution co-evolution to help software designers. We translate this reasoning technique for software designers to the five phases of process modeling. Figure 12 shows this co-evolution with the five phases of modeling in red.

Figure 12: *Design Planning and Problem-Solution [Tang, 2011]*



The modelers have to think about a high-level design plan first. What are the key design issues? What is the next phase in my modeling process? In the Problem Space and Solution Space, the modelers have to understand the problem and consider the potential solutions. The sequence flow from Problem Space to Solution Space can be considered as the method finding phase. In the Solution Space, the modeling/reconciliation is taking place. The modelers are in the problem understanding phase or validation phase from Solution Space to Problem Space. The transition from the Problem Space to the Solution phase is an iterative process.

4.5 Novel and expert modelers

What are the similarities and differences between novel and expert modelers when translating a description of a process into a BPMN model? Novel modelers have less experience with creating process models compared to expert modelers. Are experts using a different strategy when translating a description of a process into a process model? We conduct a longitudinal experiment with novel modelers. During the experiment they become more and more familiar with creating process models. What is the difference between learners and experts? What is the role of memory? We will describe some findings of previous research in several problem solving tasks in section 4.5.1. Investigating the differences between novel and experts in process modeling would be interesting for future research.

4.5.1 Previous research

Previous research is done to investigate the similarities and differences between novices and experts in various problem solving tasks.

[Batra and Davis, 1992] investigate similarities and differences between novel and expert modelers for a conceptual data modeling task. They used the think aloud method to obtain data. The results show that the time to complete the task was similar for novel and expert modelers. However, the time spent on the different levels were different for novel and expert modelers. Expert modelers made models of better quality compared to novel modelers.

Various research is done between novices and experts in the game of chess [Groot, 1966,Chase and Simon, 1973]. What is the reason why expert chess players are better compared to less expert players? Expert players search through the same number of move possibilities as novel players [Groot, 1966]. [Chase and Simon, 1973] found that working memory plays no role when comparing expert and novel players. As explained in section 4.1.2, only 7$\pm$2 elements can be stored in working memory [Miller, 1956]. Why do experts almost always win from less expert chess players? [Groot, 1966] found that expert players were much better in reproducing real game board configurations, stored in schemas. Expert players are thus much better in recognizing board configurations learned from the past when considering the next move. These board configurations are stored in long term memory. Expert players are better because they have access to board configuration knowledge, stored in long term memory, which is unavailable for novel chess players [Sweller et al., 1998].

The results of previous research raises the question whether this is also the case for novel and expert process modelers. Are expert process modelers better in creating process models compared to novel modelers because they are better in recognizing modeling patterns stored in schemas? This would be a suggestion for future research.

4.6 Conclusion

The process of process modeling can be seen as solving a problem: translating a description of a process into a process model. The limitations of the human mind play a crucial role when solving a problem. Sensory memory, working memory, and long term memory affect the problem solving task. Information stored in long term memory helps to solve new problems because you have learned from similar problems in the past. A design task can be seen as a wicked problem and consists of ten rules.

The process of process modeling is an iterative and flexible process. In this research, we assume five phases when solving a problem: problem understanding, method finding, modeling, reconciliation, and validation. Modelers read the description and try to understand the textual description in the problem understanding phase. The method finding phase is used to find a method for translating the description of the process into a BPMN model. The actual modeling is taking place in the modeling phase. The reconciliation phase is used to improve the created model. In the validation phase, the modeler checks the created model. The starting point of translating an informal description of a process into a BPMN model is reading the description, the problem understanding phase. After the problem understanding phase, it is always possible to go back and forth between the other phases.

There are similarities and differences between novices and experts in problem solving tasks. Previous research is done in various domains. The differences between novel and expert modelers is that experts have information stored in long term memory in the form of schemas.

5 Measuring the five phases in process modeling

This chapter aims to answer SQ2

SQ2 How can different phases in modeling be measured?

Is it possible to measure the five phases in process modeling? Two data generation methods, CEP and think aloud, are used in this study. Section 5.1.1 describes the applications of Cheetah Experimental Platform (CEP). Section 5.2 describes the think aloud method. How to combine the two methods is described in section 5.3.

5.1 Cheetah Experimental Platform (CEP)

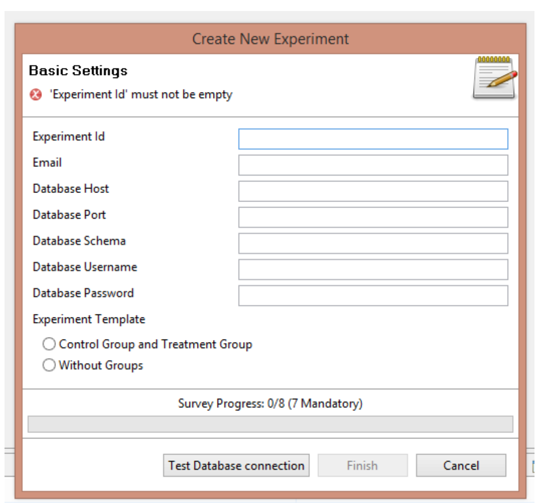
With the use of CEP, it is possible to investigate and analyze the process of process modeling. All the interactions with the modeling tool are logged. When the process of process modeling is analyzed, all the logged interactions can be replayed in the Cheetah analyzer. The modeling process consists of five phases: problem understanding, method finding, modeling, reconciliation, and validation. However, there are only interactions with the tool in the modeling and reconciliation phase. In the problem understanding, method finding, and validation phase, there are no interactions with CEP and therefore, this can be seen as a black box. CEP combines these phases into the comprehension phase. CEP records the comprehension phase when there are no modeling interactions longer than a certain threshold. To make it possible to analyze the problem understanding, method finding, and validation phase, the think aloud method is used.

5.1.1 CEP applications

Cheetah Experimental Platform (CEP) is developed by a research group of the University of Innsbruck. The tool is developed to conduct modeling experiments efficiently. CEP consists of three applications: Cheetah experimental editor, Cheetah modeler, and Cheetah analyzer.

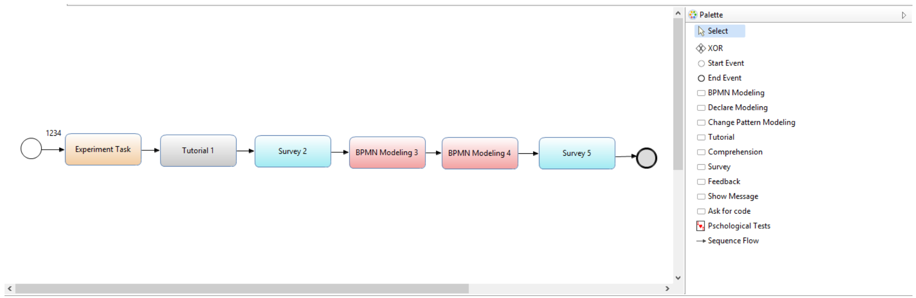
Cheetah experimental editor In the Cheetah experimental editor, it is possible to edit and design the experiment. First, the basic settings of the experiment need to be inserted. These basic settings consist of the experiment id, email address, and settings to connect a database (figure 13).

Figure 13: *Basic settings experiment*



After that, a blank experiment is created. Now an experiment can be designed. It is possible to choose different aspects of the experiment in the palette. For example a tutorial, survey, modeling task, and a feedback form. The sequence of nodes used for session 1 is shown in figure 14.

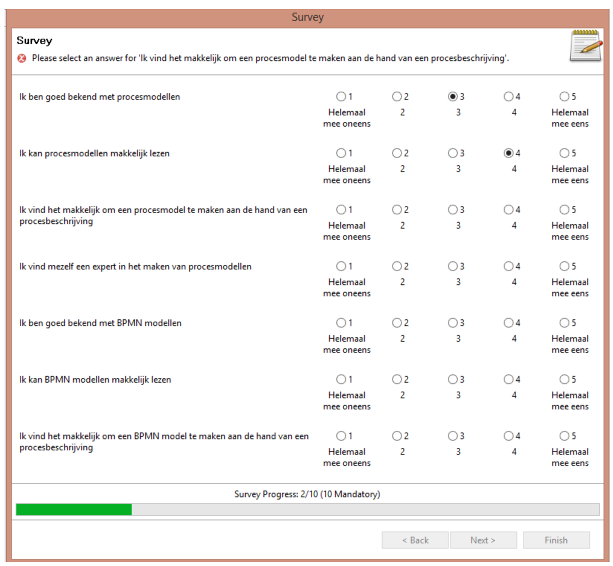
Figure 14: *Example experiment design*



Thereafter it is possible to add text questions, integer questions, and Likert scale questions to the surveys. The descriptions of the process models are added in the property section. Now it is possible to create a runnable experiment. The Cheetah modeler is used to execute the experiment.

Cheetah modeler The Cheetah modeler supports the execution of the experiments. Based on the design of the experiment created in the Cheetah Editor, successive tasks can be performed. The work flow of our experiment is shown in figure 19 and 20. It starts with a think aloud explanation. After logging in, the participants complete a survey (figure 15).

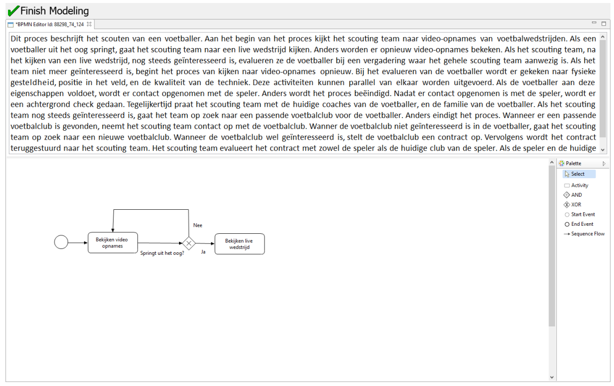
Figure 15: *Completing survey Cheetah modeler*



Then, two process models are created (figure 16), and the experiment ends with a second survey. During the experiments, data is stored locally. The data is automatically transferred to the database after the experiment. In the Cheetah analyzer, the data can be uploaded and analyzed.

Cheetah analyzer The Cheetah analyzer is used to analyze the survey and model data. The answers of the surveys are stored in the database. The data of the surveys can be exported in CSV files, which makes it possible to analyze it in for example R. Data of the modeling interactions has to be imported from the database into the analyzer. It is possible to replay the process of process modeling for all created models and to detect the comprehension, modeling, and reconciliation phase. The average comprehension, modeling, and reconciliation duration, and the total duration of the modeling task is displayed in Cheetah analyzer. More detailed information and explanation of the analyzation

Figure 16: *Modeling with Cheetah*



is given in chapter 8.

5.2 Think aloud

The second data generation method is the think aloud method. This method is mainly used for experiments where subjects need to solve a problem [Van Someren et al., 1994]. The participants of the experiment verbalize their thoughts while creating the models. The participants keep talking during modeling. With think aloud, it is possible to analyze all the five phases, problem understanding, method finding, modeling, reconciliation, and validation. Analyzing the problem understanding, method finding, and validation phase is not possible with CEP because there are no modeling interactions with the tool during these phases. The verbal utterances are recorded, transcribed, and coded. The advantage of think aloud is the possibility to analyze the problem solving task in detail. The disadvantage of the think aloud method is that it takes a lot of time to analyze the data.

The think aloud method has been used before in different types of model experiments. [Pinggera, 2014] used the think aloud method when investigating the process of process modeling. Six subjects participated in this experiment and the model consisted of 11 activities. [Haisjackl, 2016] used the think aloud method to investigate the comprehension of declarative process models. [Haisjackl and Weber, 2018] investigated how humans inspect BPMN models and focused on the identification and classification of quality issues in BPMN models. Think aloud was used to identify different strategies used when inspecting business process models. To be sure that the participants keep talking during modeling, the models should not be too easy but also not too difficult.

[Van Someren et al., 1994] described some practical protocols in think aloud experiments. (1) The setting of the experiment. This means a quiet room, a comfortable chair, and the subjects must feel at ease. (2) Instructions about the task. This will be a short instruction about the think aloud method. For example, you have to translate two textual descriptions of a process into a process model, try to say everything that comes to your mind while creating these models. (3) Warming up. Start with an example where the participants can practice their thinking aloud. (4) The behaviour of the experimenter. No questions are asked while modeling. The experimenter will only interrupt the participant when the participant stops talking. The verbal utterances are recorded. These recordings have to be of good quality and make sure that the recording instruments are working well. After that, the recordings can be transcribed and coded.

5.3 Combining CEP with think aloud

With CEP, it is possible to analyze the modeling and reconciliation phase. The problem understanding, method finding, and validation phases are combined into the comprehension phase. When the five phases in process modeling need to be analyzed, an additional method is needed. In this study the think aloud method is used. Combining CEP, for the modeling and reconciliation phase, and think aloud, for the other phases, was harder than expected. A disadvantage of focusing on the think aloud method is that it is hard to distinguish between the modeling and reconciliation phase. This is because modelers often verbalize their modeling/reconciliation interactions which are not specifically linked to a particular activity, gate, or event. [Pinggera, 2014] detected this problem as well. We decided to combine the modeling and reconciliation phase when analyzing the process of process modeling. The total number of modeling and reconciliation interactions with CEP can be measured for each created model.

5.4 Conclusion

The different phases in modeling are measured with Cheetah experimental platform (CEP), and think aloud. With CEP, it is possible to analyze the process of process modeling. CEP consists of three applications: Cheetah editor, Cheetah modeler, and Cheetah analyzer. It is possible to analyze the modeling, and reconciliation phase with CEP. The problem understanding, method finding, and validation phases are combined into the comprehension phase in CEP. With CEP the problem understanding, method finding, and validation phase can not be distinguished because there are no modeling interactions during these phases. Therefore, we use the think aloud method to make it possible to analyze all the modeling phases. In this method, the participants verbalize their thoughts while creating BPMN models. When analyzing the process of process modeling, the focus is on the think aloud method and the modeling and reconciliation phase are combined.

6 Previous research process of process modeling

In this study, we investigate the process of process modeling. Different research groups have performed several experiments in this domain with both subjects without modeling experience, as subjects with experience in business process modeling. All these experiments used CEP. Some experiments used eye tracking or think aloud together with CEP as an additional method to gather more data. A summary of the most relevant experiments with the number of subjects, level of modeling skills, models with the number of activities in the model, and the used methods is shown in table 1. A more detailed explanation of the studies is given below.

6.1 Process description variants

[Pinggera et al., 2010] investigated the process of process modeling, from an informal description to a formal process model. They varied the level of content organization. This means that the order of the informal descriptions differs but the formal process model remains the same. They used three variants of descriptions. 83 students with moderate experience in process modeling participated. A third of the group was assigned to each description variant. The model contained 24 activities and they used CEP to log all interactions. Ordering the informal description was positively related to the accuracy of the process model [Pinggera et al., 2010].

6.2 Modeling phase diagram

The quality of process models is dependent on the modeling process [Pinggera et al., 2011]. They focused on the formalization phase of process modeling and introduced the modeling phase diagram. The modeling phase diagram is a technique which logs all activities of the modeling process and visualizes the results in a diagram. The vertical axis shows the number of elements of the model and the horizontal axis time. In this paper, they emphasized the cognitive foundations of the process of process modeling. Three phases of modeling were distinguished: comprehension, modeling, and reconciliation. The process of process modeling was an iterative and flexible process. The 26 subjects were students with moderate modeling skills. The model contained 24 activities and they used CEP to analyze the process of modeling. The purpose of this research was to validate the feasibility of using a modeling phase diagram. The results show that using modeling phase diagrams is valuable for further research.

6.3 Modeling styles

[Pinggera et al., 2015] conducted an exploratory study to investigate different modeling styles. Three styles of modeling, the characteristics of these modeling styles, and which factors influence a modeling style, were identified. 115 subjects with moderate modeling experience participated. Two different models containing respectively 9 and 12 activities were used. Each subject had to translate both informal descriptions into a BPMN model. CEP was used to record and analyze the modeling styles. With CEP, the comprehension, modeling, and reconciliation phase were identified. Factors influencing modeling process models were for example number of activities, the complexity of the process (task-intrinsic characteristics), the complexity of the informal description of the process, modeling tool, notation (task-extraneous characteristics), cognitive foundations of the modeler, and experience in modeling (modeler-specific characteristics). In this research, the task-extraneous factors were constant, the task-intrinsic and modeler-specific characteristics were variable. The identified modeling styles were modeling with high efficiency, modeling emphasizing a good layout but created less efficiently, and modeling that is neither efficient nor focused on layout [Pinggera et al., 2015].

6.4 Quality process model

Not only the process of process modeling is interesting to investigate, but also the quality of the resulting model. Which process of process modeling leads to a better model? [Claes et al., 2012b] conducted an exploratory study to examine how modeling behavior relates to the quality of the model. They investigated how structured modeling, the frequency of moving objects, and the modeling speed is related to the understandability of the model. The quality of the model was measured by how easily the models could be understood. More information about the quality of process models and different frameworks to measure the quality is given in section 3.4. 103 subjects, following a graduate course on Business Process Management, participated. The subjects translated one description of a process into a BPMN model containing 12 activities. CEP was used to store and analyze the data. The results show that aspects of a particular modeling style lead to a better model and that there is strong support that structured modeling is positively related with the understandability of the model. There is also strong support that slow modeling is negatively related to the understandability. There is a mild support that frequently moving objects and reshaping the model is negatively related. The modeling speed can be used to distinguish different levels of modelers.

6.5 Eye tracking

In this qualitative study, CEP was combined with eye tracking to complement the results of previous studies with a small number of participants [Pinggera et al., 2012]. Modeling phase diagrams were combined with data collected with eye tracking [Pinggera et al., 2011]. With eye movement analysis, more detailed information was obtained about the three different modeling phases. The number of fixations and the mean duration of fixations between the textual description and the modeling area were measured. The subjects were students of computer science with moderate experience with process modeling. The subjects created a BPMN model from an informal textual description of a process. 25 subjects participated in this experiment and the process model consisted of 19 activities. The results show that the mean duration of fixations is shorter when reading the process description compared to fixations in the modeling area. On the one hand, modelers create large chunks of the model in a short period of time when an easy part of the model is created. On the other hand, the mean duration of fixations is increased when more challenging parts of the model are created.

6.6 Complexity level models

[Weber et al., 2016] conducted another exploratory study that combined CEP with eye tracking. This study presented a set of fixation patterns when translating a description of a process into a process model. These fixation patterns were used for automated activity detection in combination with CEP. With CEP, comprehension, modeling, and reconciliation phases could be distinguished. The comprehension phase consists of problem understanding, method finding, and validation, which can not be distinguished with CEP. To distinguish these phases, the automatic activity identification is extended using eye tracking. The number of fixations and gaze duration are measured with eye tracking in three areas of interest (textual description, modeling canvas, and toolbox). 120 students participated in this experiment. 30 participants were computer science students; 90 participants were psychology students. The computer science students had moderate experience with process modeling. The psychology students followed a training of two hours with an introduction to BPMN modeling. The models were divided into three complexity levels: simple, medium, and complex with respectively 12, 19, and 27 activities. The psychology students were equally distributed over the three complexity levels. The computer science students modeled only the complex modeling task. The results show five different fixation patterns. Pattern 1 shows that process modelers start with reading the textual description. Pattern 2 shows that modelers start with reading the first sentences of the textual description, followed by focusing on the modeling canvas and the toolbox. Pattern 1 and pattern 2 are both representing the comprehension phase. Pattern 3 shows a pattern of fixations prior to a modeling activity. Namely fixations on text, model, and toolbox which represents the method finding phase. Pattern 4 shows only fixations on the model. Typically part of the modeling and validation phase. Pattern 5 shows a large number of switches between the textual description and the model, the validation phase.

6.7 Think aloud

[Pinggera, 2014] wrote his dissertation about the process of process modeling and conducted several experiments to analyze the modeling process. Three modeling session were conducted to find out which activities modelers perform during the process of process modeling. In the first session, CEP was combined with the think aloud method. 6 students of computer science with moderate experience in process modeling participated and translated a description of a process into a process model. Think aloud was used to analyze the verbal utterances while creating a BPMN model. The model consisted of 11 activities. The verbal utterances were transcribed and coded according to the five modeling phases: problem understanding, method finding, modeling, reconciliation, and validation. The results show that it is possible to identify the five phases of modeling with CEP in combination with think aloud. The modeling and reconciliation phase were harder to identify than the other phases due to the relatively easy task.

6.8 Analyze modeling and reconciliation phase

The second modeling session was conducted to analyze the modeling and reconciliation phase in more detail. Eye-tracking was used to analyze this in more detail when translating a description of a process into a process model focusing on the number of fixations. 25 students of computer science,with moderate modeling experience, participated. The process model consisted of 19 activities. The results show that there are more fixations on the textual description in the comprehension phase compared to the modeling and reconciliation phases. However, the number of fixations on the textual description in the modeling phase decrease with a higher percentage compared to the reconciliation phase. The first and second modeling sessions give enough evidence that modelers are using different modeling phases when translating a description of a process into a process model.

6.9 Behavior patterns

The third modeling session investigated behavior patterns and which modeler-specific factors influence these behavior patterns. Modeling session three Was conducted with 120 students with moderate modeling experience. The subjects translated a textual description into a BPMN model. The model consisted of 24 activities and only CEP was used to obtain data. The results show three aspects indicating different behavior patterns between modelers. The first aspect is the duration of the process of process modeling phases. The second aspect is the number of phases. The third aspect is the sequence and combination of the different phases. More detailed information about these aspects can be found in [Pinggera, 2014]. Modeler-specific factors influencing the behavior patterns are, for example, domain knowledge and modeling experience.

6.10 Impact of working memory

[Martini et al., 2016] investigated the impact of working memory on process models with both inexperienced and experienced modelers. According to [Martini et al., 2016], the quality of process models depends on the experience of the process modeler, the cognitive abilities, and the process that is followed. 60 students participated. 30 participants were computer science students (moderate experience) and 30 participants were psychology students (beginners). Both groups translated the same textual description of a process into a BPMN model and the model consisted of 16 activities. The results show that there are no significant differences in the quality of the models between inexperienced and experienced modelers. The ability to remember process information in working memory did not significantly differ between inexperienced and experienced modelers. The experienced modelers were better in modeling information elements and their relations compared to inexperienced modelers.

6.11 Conclusion

The experiments described above, all investigated the process of process modeling, but with different research questions. [Pinggera et al., 2010] varied the level of content organization. Ordering the informal description was positively related to the accuracy of the process model. [Pinggera et al., 2011] investigated the usage of the modeling phase diagram. [Pinggera et al., 2015] identified three different modeling styles when translating an informal description of a process into a BPMN model. [Claes et al., 2012b] examined how modeling behavior relates to the quality of the created model. [Pinggera et al., 2012] used eye tracking in combination with CEP to obtain additional information about the modeling process. [Weber et al., 2016] used three model complexity levels and used eye tracking to identify five fixation patterns when modeling. [Pinggera, 2014] used the think aloud protocol to analyze the modeling process, used eye tracking to analyze the modeling and reconciliation phase in more detail, and investigated behavior patterns when modeling. [Martini et al., 2016] investigated the impact of working memory.

7 factors affecting modeling

This section aims to answer SQ3

SQ3 Which task specific and modeler specific factors affect the process of process modeling?

Different types of factors affect the process of process modeling which we have to take into account for this research. Some factors are already explained in previous sections. In this chapter, we will give a complete overview of these factors according to previous studies, how they affect the process of process modeling, and how to deal with these factors in this experiment. The factors are divided into task specific factors and modeler specific factors and explained in more detail in the next sections.

7.1 Task specific factors

Task specific factors are factors that are dependent on the experimental task. Examples of task specific factors are the complexity level of the task, the layout of the textual description, and the modeling language.

7.1.1 Complexity level

The complexity level of the task plays a crucial role in process modeling. Modelers experienced more difficulties when creating a more complex model compared to an easier model [Reijers and Mendling, 2011].

To support thinking aloud while modeling a process model, the models should not be too easy but also not too difficult. Too simple models could lead to less verbal utterances because the model is too obvious to model with hardly any doubts when modeling. Too difficult models could discourage the modelers to think aloud while modeling.

How can the complexity of a business process model be measured? Some papers have attempted to define and evaluate complexity metrics for business process models, mostly inspired by already existing complexity metrics in software [Cardoso et al., 2006,Gruhn and Laue, 2006]. [Cardoso et al., 2006] defined a Control-Flow Complexity (CFC) metric to define the complexity of a business process and validated the metric [Cardoso, 2006]. The complexity level of a model was determined on the basis of XOR, and AND gateways. The number of activities played no role. [Gruhn and Laue, 2006] discussed different ideas, used in other domains, to determine the complexity level of business process models. One of them is the idea of [Shao and Wang, 2003]. Cognitive weights were defined for different basic control structures in software. This approach can be a good idea for a new metric for analyzing the complexity of business process models.

In this research, we want to keep the complexity of the models the same for all modeling sessions. To determine the complexity level, we take into account the models used in previous studies and existing frameworks that determine the cognitive load of reading process models. In previous studies, defined in chapter 6, only the number of activities of the created model were considered to determine the complexity level of the task. Previous studies used business process models with 9 activities for simple process models, to 27 activities for complex process models (table 1). However, there are more elements in BPMN models that need to be take into account when determining the complexity level of a process model. For this research, we use a subset of BPMN elements (start event, end event, activities, XOR gateways, and AND gateway). Table 2 gives a complete overview of the number of activities, AND gates, and XOR gates for the models used in this experiment. In addition, the CFC metric of [Cardoso, 2006] are used to determine the complexity level of the created models. The description of the models with a possible solution of a BPMN model can be found in the appendix.

7.1.2 Layout of the textual description

[Pinggera et al., 2010] investigated three types of textual description organizations and concluded that the layout of the textual description affects the resulted model. Three types of textual descriptions were investigated: breadth-first, depth-first, and random order of the process description. With a breadth-first description of a process, the description starts with the start event and then explains the process by taking all branches into account. A depth-first description of a process, explains a whole branch before describing the other branches. The random order of a description of a process describes the events in a completely random order. The results show a significant difference in model quality

Table 2: Overview complexity level

	# activities per model	# XOR gateways	# AND gateways	CFC metric per model	CFC metric per session	# activities per session
S1M1	17	8	4	14	12,5	19
S1M2	21	6	2	11		
S2M1	17	6	6	15	12,5	19
S2M2	21	4	6	10		
S3M1	19	4	8	12	12,5	19
S3M2	19	6	6	13		
S4M1	16	8	6	15	14,5	19
S4M2	22	6	4	14		

between breadth-first and the random order of a description and between depth-first and the random order. There was no difference between breadth-first and depth-first. This means that the descriptions of our models can be either described according to the breadth-first condition or the depth-first description.

We decided to describe the business processes according to the breadth-first description. The descriptions of the models can be found in the appendices.

7.1.3 Modeling language

How does a modeling language affect the process of process modeling? [Recker and Dreiling, 2007] investigated the differences between the EPC and BPMN modeling languages. Half of the subjects had knowledge about one of the modeling languages, the other half did not have any knowledge about the other modeling language. The results show that there was no significant difference between the modeling languages. However, these modeling languages are very similar. You would expect that modelers should have more difficulties with another type of modeling language, for example, Petri net.

In this experiment we use a subset of the BPMN modeling language. All subjects have somewhat the same knowledge of the BPMN modeling language.

7.2 Modeler specific factors

Modeler specific factors are factors that are dependent on the modeler. Examples are working memory, modeling expertise, level of motivation, and process knowledge.

7.2.1 Working memory

Working memory plays an important role when solving a problem. The human brain contains a long term memory and a short term (working) memory. In your long term memory, information is stored for a longer period of time. Working memory is for storing information for a short period of time. The description of the business process is stored in working memory before creating the model. Working memory has a limited capacity [Friedenberg and Silverman, 2012]. Often, the description of the process is too long to store in working memory at once. The problem is then split into smaller parts. The long term memory is used to store information about the rules and conditions of the different gates used in BPMN (figure 7).

7.2.2 Modeling expertise

Modeling expertise affects modeling. More experience in process modeling can result in a shorter duration of the modeling task and a different strategy when creating the business process model. Some similarities and differences between inexperienced and experienced modelers in different types of problem solving tasks are explained in section 4.5. [Martini et al., 2016] investigate the impact of working memory when modeling a BPMN model. The results show that there are no significant differences in the quality of the models between experienced and inexperienced modelers. The learners of this experiment have the same modeling expertise.

7.2.3 Level of motivation

In problem solving tasks, the quality of the solution depends on the level of motivation for finding the solution. In our case: the quality of the created model is dependent on the level of motivation to create the model. Very motivated participants create models of better quality. [Cocea and Weibelzahl, 2006] investigates if the level of motivation can be estimated by analyzing log files.

7.2.4 Process knowledge

The knowledge of the process to be modeled can affect modeling. A modeler may be more familiar with a particular process compared to another process. When a modeler is more familiar, the process of process modeling could be easier [Pinggera, 2014]. If the modeler is familiar with the process is asked in the surveys. This is taken into account in the results chapter of this research.

7.2.5 Type of modeler

The personality of the modeler might affect the approach of the problem solving task [Pinggera, 2014]. Two types can be distinguished. 'Just doing it' and 'doing the right thing'. The first one refers to trial and error. The latter one refers to think about all the modeling options and decide the best option before modeling. To be able to create a good quality model, there should be a balance between 'just doing it' and 'doing the right thing.'

7.3 Conclusion

Different types of factors may affect the problem solving task, translating a description of a process into a process model. These factors are described above and are split into task specific factors and modeler specific factors. The task specific factors are the complexity level of the task, the layout of the textual description, and the modeling language. Modeler specific factors are working memory, modeling expertise, level of motivation, process knowledge, and the type of modeler. We have taken these factors into account when designing this research.

8 Experiment design

To answer SQ4, a qualitative longitudinal modeling experiment is conducted. We will observe the participants when translating a description of a process into a process model in four sessions. CEP and think aloud are used to obtain the data. This chapter defines the outline of the research design used to answer SQ4. The subjects, objects, instrumentation, and experimental execution are described. Section 8.1 gives an overview of the course 'Information systems'. The threats to validity are defined in section 8.2. Data collection and analysis is described in section 8.3

SQ4 How does the process of process modeling evolve during a longitudinal experiment where subjects have to translate a description of a process into a process model?

Subjects The subjects are first-year 'Information Science' students at Utrecht University and follow the course Information Systems. This course is a compulsory course given at the end of the first study year. Students already learned the basic principles of BPMN models. In this course, students learn about BPMN models and other modeling languages in more detail. We can, therefore, assume that all students have some basic knowledge about BPMN models at the beginning of this experiment. We will conduct the experiment four times throughout the course with the same subjects. The experiments will not take place during classes but individually in a quiet room. The subjects participate voluntarily but will receive a reward of 15 euro at the end of the course.

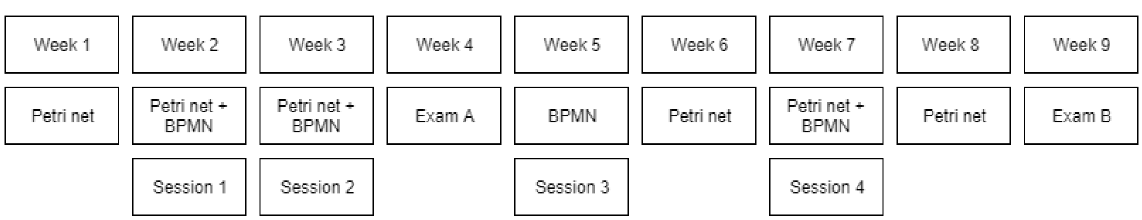
Objects There are different types of business process model languages. Think of BPMN, EPC, and Petri Net. In this research, we make use of the Business Process Model and Notation (BPMN) because this is the standard notation for modeling business processes [Genon et al., 2010]. BPMN models are used to fill the gap between the intention of the process and its implementation.

The starting point of each session is a survey with questions about the confidence rate of BPMN modeling. Next, the subjects have to create two BPMN models. Only a subsection of the BPMN elements is used for this experiment (figure 7). Each session will end with a second survey about the perceived difficulty of the modeling task. The business processes and surveys are all written in Dutch because all students are native Dutch speakers.

The process models must be at the right level. To get reliable results, the models should not be too easy but also not too difficult. The models used for the experiment are of the same level for all of the experiment sessions. In every session, the subjects need to translate two textual descriptions of a process into a BPMN model. The descriptions of the process models can be found in the appendices.

Instrumentation We will make use of the Cheetah Experimental Platform (CEP) tool. This platform is used before with similar experiments [Pinggera et al., 2011, Weber et al., 2016]. The description of the process is shown at the top of the screen. The subjects can create a BPMN model at the bottom of the screen (Figure 16). To prevent vertically scrolling, the screen is divided horizontally. In this way, the BPMN models can be drawn on the screen without the need to scroll vertically. The tool logs each step in the modeling phase of the experiment and visualizes these phases. The verbal utterances of the subjects are recorded in order to listen back and transcribe the thinking aloud process.

Figure 17: *Planning experimental execution*



Experimental execution The experiment is conducted four times. In week 1 of the course, we will conduct a pilot to make sure everything works well. The other sessions are respectively executed in week 2, week 3, week 5, and week 7 (figure 17). The duration of the experiment is about one hour. Session 1 starts with signing a consent form and some explanation about the think aloud process. Then, a BPMN tutorial is given to get used to the modeling environment of CEP (figure 18). After that, a survey with questions about the confidence rate of modeling is given. After the modeling tasks, there is another survey with questions about the perceived difficulty of the experiment. The workflow of the experiment of session 2, session 3, and session 4 is equivalent to session 1, except for signing the consent form, and the tutorial of the modeling environment (figure 20). The subjects are conducting the experiment in a quiet room but there is always somebody present to remind the subjects to voice their thoughts when needed. We decided to conduct the experiment four times with the same subjects. The subjects receive no extra information about creating process models compared to the students who do not participate in this experiment. The only information they obtain about creating process models is during lectures and modeling sessions.

Figure 18: *Tutorial*

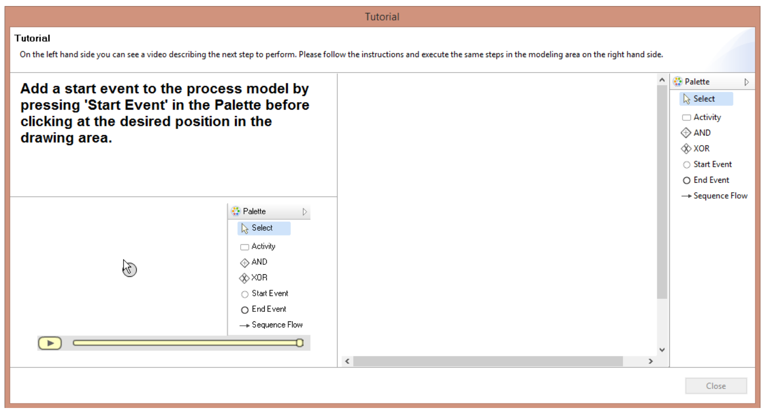


Figure 19: *Workflow experiment session 1*

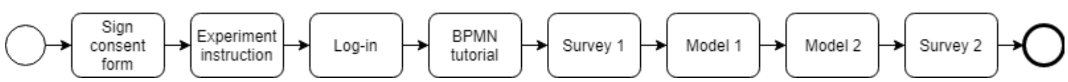
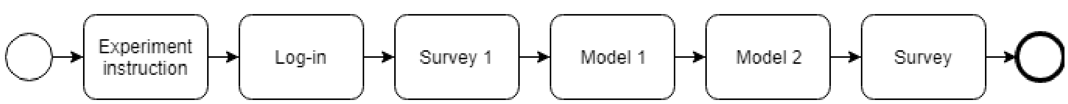


Figure 20: *Workflow experiment session 2, 3, and 4*



8.1 Course Information Systems

The participants of this experiment are following the course Information Systems at Utrecht University. This course is mandatory for all bachelor Information Science students and is given in the fourth semester of their first study year. Students learn to model and analyze information flows within an organization or system. Each week, three lectures and one modeling session are given. The lectures explain the theory about modeling. In the modeling sessions, students can practice with process modeling. Students learn two types of modeling languages, BPMN and Petri Net. The literature used for this course is:

1. van der Werf (2018), Syllabus Information Systems. Chapter 1 - Chapter 4
2. van der Aalst and Stahl (2011), Modeling Business Processes - A Petri Net-oriented approach. [van der Aalst and Stahl, 2011] Chapter 1 - Chapter 4

3. Dumas, La Rosa, Mendling, Reijers (2018), Fundamentals of Business Process Management. [Dumas et al., 2013] Chapter 1 - Chapter 5, Chapter 9

A complete overview of the schedule, lectures, topics, literature, and the experiment sessions is given in table 3.

Table 3: Course overview

Week	Day	Lecture	Topic	Literature	Experiment session
17 (22 April - 26 April)	Tuesday	Lecture 1	Introduction & Graphs	[1] Chapter 3	
	Thursday	Lecture 2	Labeled transition systems	[1] Chapter 4.1 - 4.2 [2] Chapter 1.4	
18 (29 April - 3 May)	Monday	Lecture 3	Synchronous product & Petri nets	[1] Chapter 4.4 [2] Chapter 3	
	Tuesday	Lecture 4	Petri nets	[2] Chapter 3 - 4	
	Monday/ Tuesday	Modeling session 1			
	Wednesday				Session 1
	Thursday	Lecture 5	Relation Petri net & BPMN	[3] Chapter 9 - 10	Session 1
	Friday				Session 1
19 (6 May - 10 May)	Monday	Lecture 6	Process identification & Discovery	[3] Chapter 2 , 5	Session 1
	Tuesday	Lecture 7	Petri nets & Reachability	[2] Chapter 4	
	Monday/ Tuesday	Modeling session 2			
	Wednesday				Session 2
	Thursday	Lecture 8	Workflow nets & Reduction rules		Session 2
	Friday				Session 2
20 (13 May - 17 May)	Monday		Time to ask questions		Session 2
	Thursday		Exam A		
21 (20 May - 24 May)	Monday	Lecture 9	Quantitative analysis 1 BPM		
	Tuesday	Lecture 10	Quantitative analysis 2 BPM		
	Monday/ Tuesday	Modeling session 3			
	Wednesday				Session 3
	Thursday	Lecture 11	Quantitative analysis 3 BPM		Session 3
	Friday				Session 3
22 (27 May - 31 May)	Monday	Lecture 12	Bi-simulation 1	[1] Chapter 4.3	Session 3
	Tuesday	Lecture 13	Bi-simulation 2 & Coverability 1	[2] Chapter 8.1 - 8.2	
	Monday/ Tuesday	Modeling session 4			
23 (3 June - 7 June)	Monday	Lecture 14	Coverability 2 & Invariants 1	[2] Chapter 8.1 - 8.3	
	Tuesday	Lecture 15	Invariants 2	[2] Chapter 8.3	
	Monday/ Tuesday	Modeling session 5			
	Wednesday				Session 4
	Thursday	Lecture 16	BPM		Session 4
	Friday				Session 4
24 (10 June - 14 June)	Tuesday	Lecture 17	Process mining 1	[2] Chapter 8.5	Session 4
	Thursday	Lecture 18	Process mining 2	[2] Chapter 8.5	
25 (17 June - 21 June)	Monday		Time to ask questions		
	Thursday		Exam B		
26 (24 June - 28 June)	Monday - Friday		Assignment presentations		

8.2 Threats to validity

There are some threats to validity for this study which will be considered in this section.

- **Generalizability** Due to the fact that this is a qualitative (longitudinal) experiment, the results can not be generalized. Because we combine CEP with think aloud, analyzing the data of the think aloud method takes a lot of time. Because of this, we decided to conduct a qualitative study.
- **Population validity** The students participate voluntarily in the research. Because the four sessions of the qualitative longitudinal experiment are not conducted in class time, it could be that only very motivated students will participate in the experiment.
- **Drop out participants** Because the qualitative longitudinal experiment consists of four sessions, participants are likely to drop out for any reason. We started the first session with 12 participants and ended the four sessions with 8 participants. To motivate participation in the experiment, students received a reward of 15 euro at the end of the fourth session.
- **Single modeler** In real world, it is more likely that several people are working together when creating a process model. In our experiment, a single modeler creates the models and working together is not possible.
- **Textual description** The explanation of the process is written in an informal textual description. In an organization, a piece of text with a detailed description of a business process is often not available. Working together with different stakeholders is necessary to get a complete overview of a process.

- **Think aloud** The think aloud method is a proper method when the subjects keep voicing their thoughts. To be sure of this, someone will be present at each session to alert the participant if necessary. At the beginning of the first session, the think aloud method is explained and an example is given. Nevertheless, some participants will verbalize their thoughts more easily compared to others.
- **Complexity level** We tried to keep the complexity level of the models the same. Because there are no clear complexity metrics available, it is hard to define the complexity level. More research is needed to determine the complexity level of process models.
- **Familiarity** Despite the same level of process models it is possible that modelers are more familiar with a particular process compared to another process. For example, when somebody has worked at a pizzeria, that person knows probably more about the process of ordering a pizza which can affect the modeling process.
- **Subset of BPMN elements** We used only a subset of the existing set of BPMN elements for all modeling sessions (activities, AND gates, XOR gates, and sequence flows). At the beginning of the course, the subjects learn how to create process models with the subset of elements used in this experiment, while the subjects learn modeling with more BPMN elements during the course.
- **Coding threshold** When coding the verbal utterances, a threshold of five seconds is used to code a separate phase. Phases with a duration of shorter than five seconds are not coded. This can affect the number of coded phases.

8.3 Data collection and analysis

To answer SQ4, we will conduct a longitudinal qualitative experiment consisting of four sessions with eight participants. The goal of the fourth research question is to find out if and how the subjects the five phases of modeling, problem understanding, method finding, modeling, reconciliation, and validation, apply. Data collection and analysis of session 1 is the starting point of our experiment. Students have to translate two descriptions of a process into a BPMN model and fill in two surveys, at the beginning and at the end of each session. To analyze the different model strategies, we used five modeling phases [Weber et al., 2016]. Several analyze functions of CEP, together with the analysis of the think aloud process, are used to answer research question 4.

8.3.1 CEP

With the use of CEP, it is possible to store all answers to the surveys on a local hard drive. Also, the data of the surveys can be exported in CSV files to make it possible to analyze the data in, for example, R. Open, closed, and Likert scale questions are supported. We will analyze the answers to these questions to compare, for example, the confidence rate in modeling process models throughout the four sessions.

CEP makes it also possible to log all interactions with the modeling environment and replay the process at any time. In this way, all intermediate steps of creating the model can be analyzed. It is possible to analyze the modeling, reconciliation, and comprehension phase semi-automatically. As said before, the problem understanding, method finding, and validation phases are combined and called the comprehension phase. The modeling interactions are mapped to the different phases. Creating and deleting elements of the model say something about the modeling phase. Moving and renaming elements say something about the reconciliation phase. Table 4 shows an overview of the comprehension, modeling, and reconciliation phases and which modeling actions are part of these phases. The comprehension phase is identified when there is no interaction with the system longer than a certain threshold. When there is, for example, only one modeling step in a longer series of reconciliation steps, the modeling step is not seen as a separate modeling phase. For each created model, the sequence of phases, the duration of each phase, the total duration for each phase, and the average duration of each phase is given in CEP. All the possible interactions with CEP are described in more detail in table 5 [Pinggera, 2014].

The problem understanding, method finding, and validation phase are all cognitive phases and more like a black box for CEP. For example, the duration from reading the textual description of the process to start modeling will say something about the problem understanding phase and the method finding phase but is not measurable with CEP. These phases are measured with the help of think aloud. For analyzing the different phases in the process of process modeling, we will focus on the think aloud method for this research.

Table 4: Modeling interactions CEP

Comprehension	**Modeling**	**Reconciliation**
No modeling interactions	Creating elements Deleting elements Reconnecting edges Adding/deleting edges	Moving elements Renaming elements Laying out edges Updating edges

Table 5: Recorded interactions CEP [Pinggera, 2014]

Interaction	**Description**
Create node	Create an activity, gateway, or event
Delete node	Delete an activity, gateway, or event
Move node	Move an activity, gateway, or event
Create edge	Create an edge connecting two nodes
Delete edge	Delete an edge
Reconnect edge	Reconnect an edge between two nodes
Move edge label	Move the label of an edge condition
Create/delete/move edge bend point	Update the routing of an edge
Create condition	Create an edge condition
Delete condition	Delete an edge condition
Update condition	Update an edge condition
Rename	Rename an activity
Vscroll	Scroll vertically
Hscroll	Scroll horizontally

8.3.2 Think aloud

The think aloud method makes it possible to analyze the cognitive processes during the process of process modeling. With this method, it is possible to analyze the problem understanding, method finding, modeling/reconciliation, and the validation phase. As explained in chapter 5, we combined the modeling and reconciliation phase due to the difficulties of distinguishing the modeling and reconciliation phase with think aloud. With the help of CEP, it is possible to analyze the total number of modeling and reconciliation interactions for each created model.

The process starts with recording the verbal utterances. After that, the verbal utterances are transcribed for each subject and coded with the corresponding time stamps. We used NVivo to support the coding process. The coding tree is divided into the five steps of modeling and an "other" node for verbal utterances not part of one of the five phases (figure 21). Finally, the findings of the verbal utterances are documented. A threshold of 5 seconds is used for coding another phase. For example: A modeler is reading the textual description of the process. For a period of 3 seconds, the modeler adds a start event to the modeling canvas and continues with reading the textual description. The three seconds of modeling is not detected as a separate modeling/reconciliation phase but just as one problem understanding phase. Table 6 gives some examples of verbal utterances for each phase. An explanation of each phase is given below.

Problem understanding In the problem understanding phase, the modelers try to understand the textual description. The verbal utterances are coded as the problem understanding phase when modelers read the textual description or when they are reasoning about the textual description.

Method finding This phase is used to find a method to translate the textual description into a process model. The method finding phase is detected when the modeler tries to translate the acquired knowledge of the textual description to specific BPMN elements.

Modeling/Reconciliation The modeling/reconciliation phase is where the actual modeling is taking place. Creating elements, deleting elements, moving elements, renaming elements are all elements of this phase. Verbal utterances are coded as the modeling/reconciliation phase when the modeler is interacting with the modeling canvas.

Validation Modelers check their created models in the validation phase. Verbal utterances are coded as validation when the modeler explicitly uttered that he or she is going to check the created model.

Other Verbal utterances that are not part of the four phases above are coded as 'other'.

Figure 21: *Coding tree*

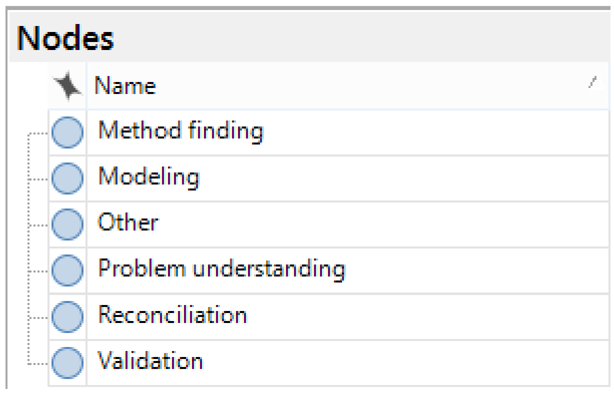


Table 6: Examples verbal utterances

Problem understanding	"First I am going to read the process description"
Method finding	"Now I am thinking: what is the best option to model this?"
Modeling	"I am going to add an activity"
Reconciliation	"I make this a little bit clearer"
Validation	"Okay, I am going to check my created model"

8.3.3 Combining CEP with Think aloud

When all data is collected with the help of CEP and think aloud, we have to combine this data. Unfortunately, the Cheetah analyzer did not worked as we expected. All modeling interactions of each modeler are stored in a MXML file but it was not possible to replay the process of process modeling in the Cheetah analyzer. We focused on the verbal utterances of the think aloud method to analyze the different phases and modeling strategies. With the think aloud method, it is very hard to distinguish the modeling and reconciliation phase because the verbal utterances of the modeling and reconciliation phase are often not specifically linked to a certain activity or gate. Hence, the modeling and reconciliation phases are combined. The verbal utterances are transcribed, coded, and analyzed.

The results of the surveys, at the beginning, and at the end of each session, are stored in separate XML files. It is possible to analyze these results in, for example, R or Excel. The answers of the surveys say something about the confidence subjects have at the start of each session and the perceived difficulty level at the end of each session.

9 Results per subject and model

This chapter, together with chapter 10, shows the results of this experiment. To show the results as clearly as possible, they are divided into results per subject and model (chapter 9), and results per phase (chapter 10).

This chapter displays the results of the qualitative longitudinal experiment per participant and model. In session 1, we started with 12 subjects. 8 subjects were left over after session 1 and completed all four sessions. Two of them did not show up for the second session and for two subjects, it was too difficult to verbalize their thoughts during modeling. Unfortunately, we had to eliminate the results of one subject at the end of session 4 due to different reasons. The subject was late for two sessions and in a hurry. The subject was also very chaotic in his process of process modeling. Ultimately, we have 7 subjects to analyze their modeling strategy. As said before, there are 4 modeling sessions. The subjects had to create two models in each modeling session. In the end, we had 56 models to analyze.

The purpose of visualizing the results for all subjects and models is to identify different approaches and strategies when solving a problem and whether the strategies evolve over time. At the end of this chapter it is possible to answer SQ4.1, and SQ4.2.

SQ4.1: Which modeling strategies are used when translating a description of a process into a process model?

SQ4.2 Does the strategy change during the sessions?

Section 9.1 defines the course results for each subject. Section 9.2 defines the possible modeling strategies we have seen in this experiment and whether the modeling strategies evolve during the sessions. Section 9.3 describes the results per model. The course results, in relation with the used strategies is explained in section 9.4. A discussion of the findings is given in section 9.5. The answers to research questions 4.1 and 4.2 are given in section 9.6.

For all figures, the same colours are used to represent the phases. The problem understanding phase is colored orange. The method finding phase is green-colored. The modeling/reconciliation phase is red-colored. The validation phase purple-colored, and the other phase is blue colored (figure 22). All figures, representing the modeling approach, are displayed in appendix F.

Figure 22: *Colours used for each phase*

9.1 Course results

Table 7 shows the course results of the subjects. As said in the research design section, all subjects followed the Information Systems course during this experiment where students learn how to create process models. Table 7 shows the results of the two exams and the final grade. The result of exam A counts for 10 percent of the final grade. Exam B counts for 50 percent of the final grade. The fourth column shows the weighted average of the two exams. If the subject made the retake exam, the grade is shown in the fifth column. The sixth column shows the final grade of the course which also includes the assignment grade, which counts for 40 percent.

The average grade of the two exams of the subjects who participated in this experiment is a 6,4. Including the retake, the average grade is a 6,8. The grade for the retake exam replaces both exam A and exam B. The average grade of the final result is a 6,9 for the subjects who participated in this experiment. The average grade for both exams is a 6,9 for all students who passed the course and a 4,0 for all students who did not pass the course. The results of the subset of students who participated in this experiment are thus representative for all students who passed both exams.

Table 7: Course results

	Exam A (10%)	Exam B (50%)	Mean A + B	Retake	End result
Subject 1	6,7	5,3	5,5	-	5,9
Subject 2	6,7	4,7	5,4	7,2	6,7
Subject 3	6,8	6,6	6,6	-	6,8
Subject 4	6,2	4,8	5,9	7	7,1
Subject 5	6,3	6,3	6,3	-	6,2
Subject 6	8	8,1	8,1	-	8,1
Subject 7	5,1	7,3	6,9	-	7,4
Mean	6,5	6,2	6,4	6,8	6,9

9.2 Modeling strategies

This section describes the different modeling strategies of each subject and whether the modeling strategies evolve during the sessions. In appendix F, the modeling patterns, sequence of phases, the number of phases, the modeling duration, and the answers to the survey questions are visualized in different types of figures for each subject with a detailed explanation of the results. With these different types of figures, it is not possible to show all information about the used modeling strategies. For example, one of the modeling strategies is to model all the activities and gateways first, before modeling the sequence flows between the activities and gateways. These modeling interactions are detected as the modeling/reconciliation phase but it is not possible to distinguish these differences from the figures. In this section, we will give a summary of the results shown in appendix F. We will describe the modeling strategies per subject, together with some remarks of the figures in appendix F.

- **Subject 1** The modeler starts with reading the whole textual description first before moving to another phase. Except for the first problem understanding phase, there are relatively short problem understanding phases in the rest of the process of process modeling. In the first two sessions, there are some method finding phases. After session 2 (except for session 3, model 2) there are no method finding phases coded anymore. This seems that it was no longer necessary to think aloud the possible modeling options. In the last two sessions, the modeler verbalized only problem understanding and modeling/reconciliation utterances. Only 1% of the phases is coded as the validation phase. The subject experienced some modeling problems because it was not possible for the subject to model two gates in a row. There always had to be an activity in between. This sometimes caused some modeling doubts.

  Strategy evolution The modeler used the same strategy during the sessions. The modeler starts with reading the whole description of the process. Modeled the process models step by step including activities, gateways, and sequence flows with the corresponding conditions and do not used the validation phase to check the created models.

- **Subject 2** In session 1, model 1 the modeler reads the whole textual description first before the modeler continues with modeling. For the rest of the models, the modeler reads a small part of the textual description and starts modeling immediately. It is remarkable that only in session 2, model 1 multiple validation phases are coded. In the rest of the models, there are no validation phased coded at all. The verbal utterances show that the subject had difficulties with some parts of the textual description for this model and wanted to check the created model. However, the survey answers show that the subject experienced the second model of session 2 as more difficult while no validation utterances are coded in the second model. The verbal utterances were very chaotic at the beginning of this experiment. The subject had to read parts of the textual description multiple times in the problem understanding phase before it was possible to translate it into BPMN elements. During the sessions, the strategy changed and the verbal utterances became less chaotic. The modeler modeled many activities. Instead of using conditions in combination with sequence flows, the conditions are all modeled as activities.

Strategy evolution The strategy of subject 2 changed during the sessions. Starts in S1M1 with reading the whole textual description. For the rest of the models, only the first sentence of the text is read before modeling. In the first two sessions, the modeler modeled step by step. In session 3 and session 4, the subject modeled the sequence flows at the end of the process and starts with modeling all the activities and gateways. Furthermore, the subject used the validation phase only in S2M1.

- **Subject 3** In the first two sessions, most of the verbal utterances are coded as the problem understanding and modeling/reconciliation phase with a few short validation phases at the end of the modeling process. The subject checked the created models very quickly before adding some changes or ending the modeling process. In session 3 and 4, there are no validation phases coded anymore. Apparently, it was no longer necessary to check the created models. In session 1 model 1 the subject reads the whole textual description first. In the rest of the models, the subject reads the first sentence in the textual description and starts modeling right afterwards. Almost all modeling interactions go from the problem understand phase to the modeling/reconciliation phase and from the modeling/reconciliation phase to the problem understanding phase. Furthermore. There was no need to think about the possible modeling options because there are no method finding phases coded. It seems that the subject is very confident about his/her modeling skills. The survey answers confirm this. The subject had no troubles with understanding the textual description as well as creating the process models.

  Strategy evolution To summarize, the strategy of subject 3 changed. Starts in S1M1 with reading the whole textual description. After S1M1, only a small part of the textual description is read before modeling. The modeler modeled step by step and checked the created models only in the first two sessions.

- **Subject 4** Subject 4 starts immediately with adding activities to the modeling canvas without reading the textual description of the process first. The modeler starts with modeling all the activities, followed by modeling the sequence flows and adding conditions. This explains the relatively long modeling/reconciliation phases at the end of the modeling process. In the first three models, there are multiple method finding phases. In the last two sessions, there are almost no method finding phases coded anymore. The modeler used almost no separate validation phases but checked the created models while modeling the sequence flows at the end of the process. The problem understanding phases have a short duration in combination with much longer modeling/reconciliation phases. Compared to the other subjects, there are a lot of method finding phases coded. This subject has a consistent modeling strategy during the sessions and had some modeling doubts about modeling parallel activities. The subject was not very confident about his/her modeling capacities and found it challenging to create the BPMN models.

  Strategy evolution This subject never reads the whole textual description but starts with modeling immediately and always modeled the activities and gateways first. At the end of the process, the sequence flows are modeled. There are some very short validation phases coded in four models. Overall, the subject used the same strategy during the sessions.

- **Subject 5** The modeler started in S1M1 with reading the whole textual description first. In the second model of the first session, the subject tried to read a small piece of the textual description before started with modeling. After some modeling actions, the subject decided to read the entire textual description. In the other sessions, the subject read the whole textual description first to get a complete overview of the process. The modeling/reconciliation phases are often interrupted by short problem understanding phases during the process of process modeling. The problem understanding phase is important during the whole process. The textual description is often read multiple times before the modeler understands it and able to translate it to BPMN model elements. Method finding phases are coded in all sessions. In addition, it stands out that the modeler does not check the created model in the validation phase. Compared to the other participants, this subject had the longest modeling duration for 5 of the 8 models.

Strategy evolution Overall, the modeler creates the process models according to the same strategy during the sessions and modeled step by step. All the activities, gateways, and sequence flows are modeled before going back to read the next part of the textual description. The process of process modeling is often interrupted by reconciliation actions to ensure the layout of the model. Furthermore, no validation are coded.

- **Subject 6** The modeler starts with reading the whole textual description and always ends with one or more validation phases. After reading the whole textual description, the subject modeled the process model in small chunks of modeling/reconciliation steps with always going back to the problem understanding phase to find out the next step of modeling. At the end of each model, the modeler checked the created model for any mistakes and solved the mistakes when needed in the modeling/reconciliation phase.

  Strategy evolution The subject used the same modeling strategy during the sessions. The subject modeled the process models step by step with modeling the activities, gateways, and sequence flows first before going back to the problem understanding phase. The subject always ends with one or more validation phases to check the created model.

- **Subject 7** The modeler first reads the whole textual description before moving on to the modeling/reconciliation phase. Large chunks of modeling/reconciliation are combined with shorter chunks of modeling. Except for S1M1, there are method finding phases coded in all models. The subject thinks about the possible modeling options in the method finding phase to find the best way to model the textual description. In session 1 and session 3, there are some short validation phases. In the other sessions, there are no validation phases coded.

  Strategy evolution Overall, the subject add the modeling elements step by step to the modeling canvas and used the same strategy for all sessions. For more difficult parts in the process, the modeler considers the possible modeling options first, before adding modeling elements. Only in S3M1, two short validation phases are coded.

According to the information described above, which modeling strategies can be distinguished? The used strategy depends on whether or not reading the whole textual description first, whether or not using the validation phase to check the created model, and in which order the BPMN elements are modeled. The method finding phase seems to be dependent of modeler specific factors in stead of using a particular strategy. 6 modeling strategies can be distinguished (table 8). For each strategy, an example of a possible modeling behavior figure is given in figure 23.

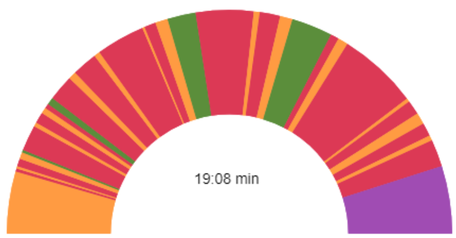
An overview of which strategies the subjects used is given in table 9. As can be seen in table 9, four subjects used the same strategy during all the sessions (subject 1, subject 5, subject 6, and subject 7). Subject 4 used two different strategies (E and F). Subject 2 used four different strategies during the sessions (B,C,D,E). Subject 3 used three different strategies during the sessions (A,C,D). Strategy F is only used by subject 4. Strategy D is only used by subject 3.

9.3 Results per model

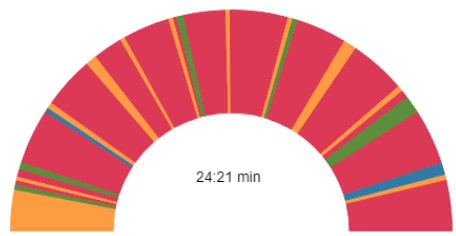
The figures, displaying the results per model, are shown in appendix G. The number of phases and duration of each phase are displayed as column charts.

In session 1 of this experiment, the subjects had to create a process model of a mortgage request, and a second model, describing the process of preparing for take-off of an airplane. The second session consists of a process describing the scouting process of a soccer player and a process describing aid in disaster areas. The first model of the third session describes a legislative proposal. The second model describes the process of building a house. The fourth session starts with a process describing the process of switching to a new telephone provider. The experiment ends with a process describing the preparation of a tarte tatin (appendix B, C, D, E).

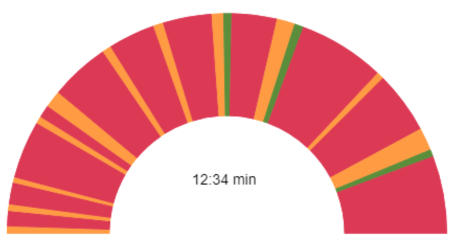
Unfortunately, studying the results per model did not yield any relevant findings. The results per phase did yield relevant findings and are defined in chapter 10.



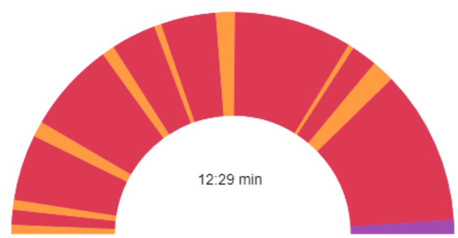
(a) Strategy A



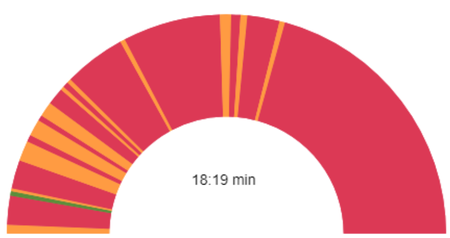
(b) Strategy B



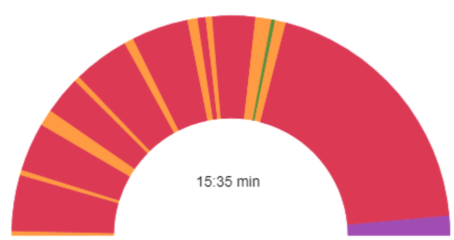
(c) Strategy C



(d) Strategy D



(e) Strategy E



(f) Strategy F

Figure 23: Examples modeling strategies

Table 8: Modeling strategies

	Strategy
A	Start with reading the whole textual description of the process to get a complete overview of the process. Model the BPMN elements step by step to the modeling canvas. Use the validation phase at the end of the process to check the created model.
B	Start with reading the whole textual description of the process and add BPMN elements step by step to the modeling canvas. Do not use the validation phase at the end of the process.
C	Start with reading a small part of the textual description and add BPMN elements to the modeling canvas right afterwards. Model the BPMN elements step by step and do not use the validation phase.
D	Start with reading a small part of the textual description and add BPMN elements to the modeling canvas right afterwards. Model the BPMN elements step by step and check the created model in the validation phase.
E	Start with reading a small part of the textual description and add BPMN elements to the modeling canvas right afterwards. Model all the activities and gateways first and finish the modeling process with adding all the sequence flows. Do not use the validation phase to check the created model.
F	Start with reading a small part of the textual description and add BPMN elements to the modeling canvas right afterwards. Model all the activities and gateways first and finish the modeling process with adding all the sequence flows. Check the created model in the validation phase.

Table 9: Used strategies

	Strategy							
	S1M1	**S1M2**	**S2M1**	**S2M2**	**S3M1**	**S3M2**	**S4M1**	**S4M2**
Subject 1	B	B	B	B	B	B	B	B
Subject 2	B	C	D	C	E	E	E	E
Subject 3	A	D	D	D	C	C	C	C
Subject 4	E	F	E	F	F	F	E	E
Subject 5	B	B	B	B	B	B	B	B
Subject 6	A	A	A	A	A	A	A	A
Subject 7	B	B	B	B	B	B	B	B

9.4 Course results and used strategy

The course results are shown in table 7. Both exams contain a question where students have to translate a textual description of a process into a process model. Subject 6 scores considerably better compared to the other subjects. Is this reflected in the used strategy in this experiment? The results in section 9.2 show that subject 6 used the same strategy during the session (strategy A). Starting with reading the textual description to get a complete overview of the process. Next, the subject modeled the process in relatively small chunks of modeling/reconciliation steps with modeling the activities, gateways, and sequence flows. The modeler always checked the model at the end of the process in one or more validation phases.

In contrast with the other subjects, subject 6 is the only participant who used strategy A for all modeling sessions. Other subjects changed their strategies during the sessions or used other strategies. The rest of the subjects used the validation phase rarely whereas subject 6 used the validation phase in every model. According the results of this experiment, we can conclude that a consistent strategy consisting of reading the textual description, modeling step by step, and checking the created model, contributes to better course results.

9.5 Discussion

Section 9.2, together with appendix F, contains much information about the used strategies per participant. In this section, we will give a summary of the used strategies together with some findings in previous research.

[Pinggera et al., 2015, Claes et al., 2012b] conducted experiments to distinguish different modeling styles. As described in section 6.3, and section 6.4, [Pinggera et al., 2015] distinguished three modeling styles. Modeling with high efficiency, modeling emphasizing a good layout, and modeling that is neither efficient nor focused on layout. [Claes et al., 2012b] showed that aspects of a particular modeling style leads to a better model. Structured modeling is positively related with the understandability of the model. [Claes et al., 2012b] defined structured modeling as "focusing on a specific, bounded part of the model and finishing it before starting to work on another part". Slow modeling is negatively related with the understandability of the model. Furthermore, there is a mild support that frequently moving objects is negatively related. Previous research described different modeling styles but did not investigated different modeling strategies during the process of process modeling.

In this chapter, we described different modeling strategies per subject and whether the subjects used the same strategy during the sessions. We distinguished six different modeling strategies (table 8). Four subjects used the same strategy during the sessions. Three of them used strategy B during the four sessions. They started with reading the whole textual description, modeled step by step, and do not used the validation phase to check the created models. One of them used strategy A and started with reading the whole textual description, modeled step by step, and checked all the created models in the validation phase. This strategy corresponds with the best course result. Three subjects changed their strategy. Subject 2 used strategy B, C, D, and E. Subject 3 used strategy A, C, and D. Subject 4 used strategy E and F.

The modelers become more familiar with the modeling language and the problem solving task during the sessions. The differences between the subjects per phase and how this will affect the number of different phases and the duration of the phases is shown in chapter 10.

9.6 Conclusion

It is now possible to answer SQ4.1 and SQ4.2

SQ4.1: Which modeling strategies are used when translating a description of a process into a process model?

Different strategies are used to create business process models from an informal textual description. Different approaches are used for solving a problem, translating a description of a process into a process model. Some modelers read the full textual description of the process in the problem understanding phase first, before moving on to one of the next phases. Others started with modeling/reconciliation immediately. Some subjects modeled step by step, other subjects modeled all the activities and gateways first and end with modeling all the sequence flows. Some modelers validate their created model always at the end of the process. Others do not validate their created process model at all. An overview of all modeling strategies is given in table 8.

SQ4.2 Does the strategy change during the sessions?

For some modelers, the strategies do change during the sessions. 3 subjects changed their strategy. 4 subjects do not changed the strategy for translating an informal textual description into a process model.

Almost all subjects needed the most time for creating the first model in the first modeling session. For 5 of the 7 participants, the number of phases is again the highest in session 1 model 1. Overall, most of the transitions are between the problem understanding phase and the modeling/reconciliation phase shown in the modeling patterns figures.

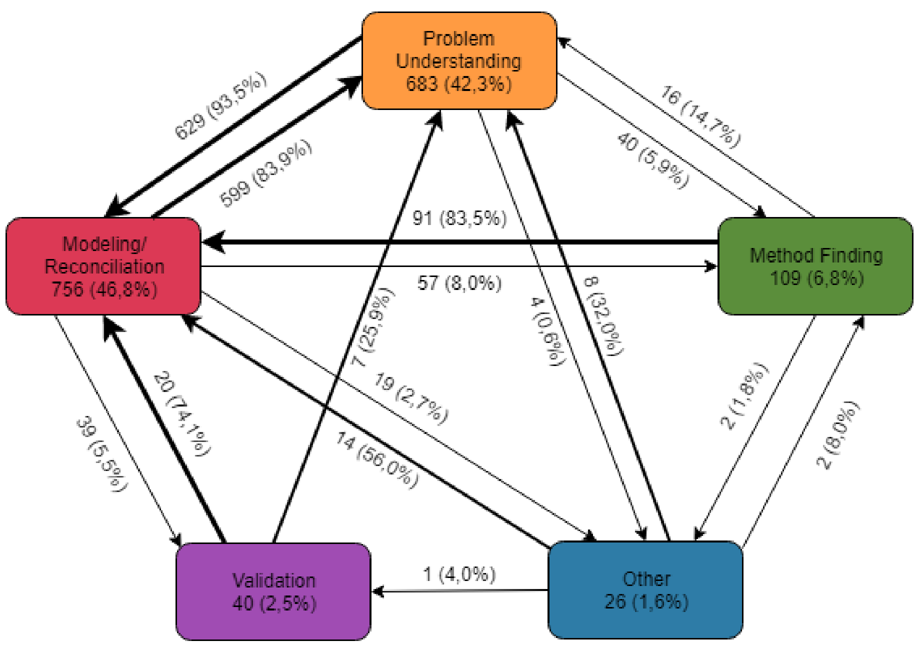
10 Results per phase

In this chapter, the results per phase are shown. Each subsection describes one of the modeling phases. For each phase, the number of phases, the total duration, and the average duration is displayed in boxplots. In addition, the results are split into results per model and results per session. The results per session are the average results of model 1 and model 2 of that particular session. Comparing the results per session is relevant because as described in section 7.1.1, and table 2, the CFC metric per session and the number of activities per session are equivalent. Except for a small difference in CFC value for session 4. First, an overview of the modeling patterns of all created models is given in section 10.1.

10.1 Modeling patterns

Figure 24 shows the modeling patterns for all created models. In total, 1614 phases are coded during the modeling sessions. The boxes show the number of phases. For example, there are 683 problem understanding phases coded which is 42,3% of the total number of 1614 coded phases. The transitions between the phases are displayed by arrows. For example, there are 629 transitions from the problem understanding phase to the modeling/reconciliation phase which is 93,5% of all transitions starting in the problem understanding phase. No arrow means that there are no transitions coded between these phases. The percentage of the transitions determines the thickness of the arrow. For percentages up to 20%, line thickness one is used. For 20% - 70% line thickness two is used. For percentages higher than 70%, line thickness three is used.

Figure 24: *Modeling patterns*

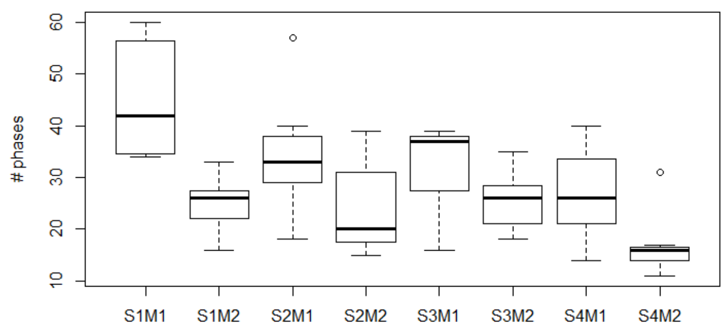


The problem understanding phase, and the modeling/reconciliation phase capture the most coded phases as well as the most coded transitions between these phases. There are no transitions at all coded from the problem understanding phase to the validation phase. There is only a limited number of validation phases coded. Most of the transitions, starting in the validation phase, go to the modeling/reconciliation phase (74,1%). Most of the transitions, starting in the method finding phase, go to the modeling/reconciliation phase (83,5%).

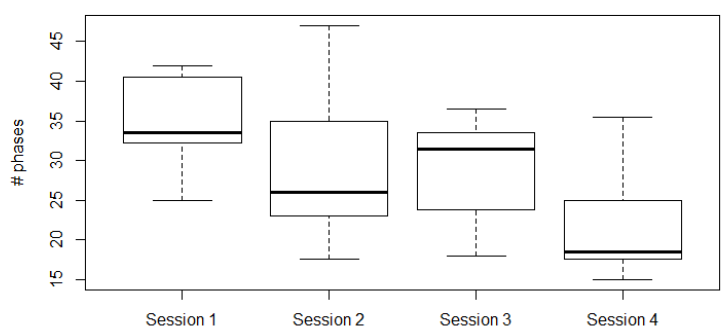
Figure 24 gives an overview of the number of phases and the most common transitions between the phases. In the next sections, the results per phase are defined in more detail.

10.2 Number of phases and modeling time

Other studies in the process of process modeling, showed that there is a large variance in the number of phases and the total modeling duration [Pinggera, 2014]. This variation can be caused by different modeling strategies and how the five phases in process modeling are combined. How often must the textual description be read again in the problem understanding phase before moving on to one of the other phases? How much time is needed to understand the textual description describing the business process? The variance in the modeling/reconciliation phase can be caused by quicker or slower adding/deleting/moving modeling/reconciliation elements or how much time is spent on the layout of the model. The variance in the method finding phase can be caused by the knowledge of the modeling language and experience in process modeling. The variance in the validation phase can be caused by that modelers do not think it is valuable to check the created model. These observations are used to describe reoccurring behavior patterns in the process of process modeling [Pinggera, 2014]. As described above, these behavior patterns are based on one created model per participant. What is changing when the participants have to create multiple process models in a longitudinal experiment during a course where the subjects learn how to create process models?



(a) Per model



(b) Per session

Figure 25: Number of phases

Figure 25 shows the total number of phases per model (a) and per session (b). In figure 24a, the results are displayed as boxplots for each created model. In figure 24b, the average number of phases for model 1 and model 2 of each session are summed up and divided by 2. The minimum, maximum, mean, and standard deviation values are shown in the tables, below the corresponding graphs.

	min	max	mean	SD
S1M1	34	60	45,4	11,8
S1M2	16	33	24,9	5,7
S2M1	18	57	34,6	12,2
S2M2	15	39	24,4	9,8
S3M1	16	39	31,9	8,8
S3M2	18	35	25,4	5,9
S4M1	14	40	27,0	9,2
S4M2	11	31	17,0	6,5

Table 10: Number of phases per model

	min	max	mean	SD
S1	25	42	35,1	6,2
S2	17,5	47	29,5	10,5
S3	18	36,5	28,6	6,8
S4	15	35,5	22,0	7,1

Table 11: Number of phases per session

We coded a large variance in the number of modeling phases for S1M1 and S2M1 (table 10). A large variance results in a large standard deviation. For S1M1, the minimum value of the number of phases is 34. The maximum value of the number of phases is 60. Without the minimum value of 34 phases, the average value is 47,3. Without the maximum value of 60 phases, the average value is 43. Although there is a large variance, both values are still significantly higher compared to the other models. For S2M1, the minimum value is 18. The maximum value is 57. Without the minimum value, the average value is 37,3. Without the maximum value, the average value is 30,8. Although there is a large variance, both values are significantly higher compared to the second model of the first session, and compared to the second model of the second session. Figure 25a shows that the second model of each session has a fewer number of modeling phases compared to the first one. Figure 25b shows that the average number of phases decreases during the sessions. This means that there are fewer transitions between the phases in the last session compared to the first one.

Finding 1: During the sessions, fewer phases are needed to create the process model. Fewer phases result in fewer transitions which indicate that less switching between phases is needed to complete the process model.

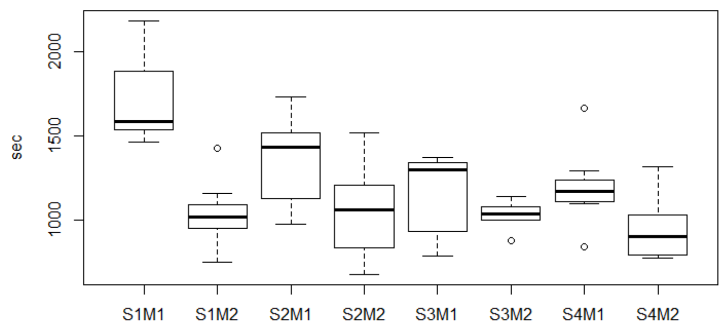
	min	max	mean	SD
S1M1	24:23	36:19	28:45	04:33
S1M2	12:34	23:47	17:24	03:29
S2M1	16:20	28:50	22:29	04:34
S2M2	11:23	25:18	17:32	04:57
S3M1	13:08	22:54	19:06	04:14
S3M2	14:42	19:01	17:13	01:23
S4M1	14:03	27:43	19:56	04:07
S4M2	12:56	21:56	15:51	03:18

Table 12: Modeling duration per model

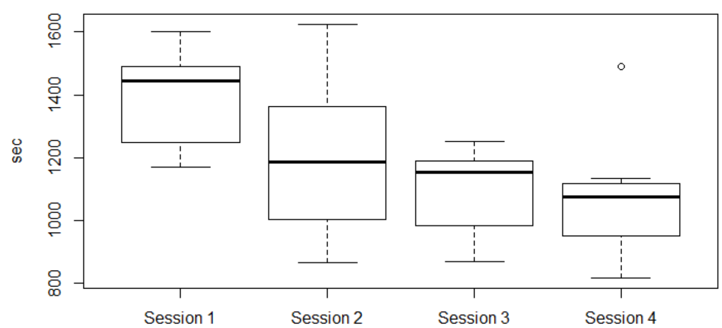
	min	max	mean	SD
S1	19:29	26:40	23:04	02:43
S2	14:24	27:04	20:00	04:37
S3	14:31	20:52	18:09	02:24
S4	13:37	24:49	17:54	03:33

Table 13: Modeling duration per session

Figure 26 shows the modeling duration. The number of phases decreases during the sessions. The modeling



(a) Per model



(b) Per session

Figure 26: Modeling duration

duration decreases from an average of 23:04 minutes to 17:54 minutes which is a modeling duration decrease of 05:10 minutes during four sessions. The overall minimum modeling duration is 11:23 minutes in S2M2. The overall maximum modeling duration is 36:19 minutes in S1M1. Figure 26b shows a decrease in modeling duration. The long modeling duration of the first model can be caused by the fact that modelers have to get used to the modeling environment, and the problem solving task. The difference in modeling duration between inexperienced and experienced modelers is investigated by [Martini et al., 2016] and described in section 6.10. The results show that there are no significant differences in the quality of the created process models between inexperienced and experienced modelers, but inexperienced modelers needed significantly more time. However, what is the definition of an experienced and inexperienced modeler? In which category belong the subjects participated in this experiment? The results of this experiment show that there is a minor decrease in process modeling duration.

Finding 2: There is a decrease in modeling duration, with an outlier for the first created model. This can be caused by the fact that modelers have to get used to the modeling environment, and the problem solving task.

Overall, there is a decrease in the number of phases and a decrease in the modeling duration. The first model of the first session contains considerably more phases and a longer modeling duration compared to the other models. What changes specifically in each phase? These changes are described in the next sections.

10.3 Problem Understanding

According to [Pinggera, 2014], there are differences in the initial problem understanding phase. Some modelers invest more time to read and understand the textual description, and to get a complete overview of the process model. Others start with modeling after a short period in the problem understanding phase. We detected these differences as well. Four subjects read the textual description first, before moving on to the next phase. Two subjects read the whole textual description in S1M1 but changed their strategies after the first model. One subject never read the whole textual description first but started modeling right away. [Pinggera, 2014] found a correlation between familiarity with the process and the initial comprehension duration. According to the results of this experiment, subject 2 and subject 3 changed their strategy after S1M1, while the familiarity score of both subjects is 1, for both S1M1 as well as for S1M2. These subjects changed their strategy while the familiarity score remains the same. Subject 4 never read the textual description, while giving scores of 1 and 2 to familiarity. The other subjects do not change their strategy independent of the familiarity scores. According to the results of this experiment, we can conclude that whether or not reading the textual description first is dependent on the strategy used and independent of the familiarity score.

Finding 3: Whether or not reading the whole textual description first is dependent on the used strategy and independent of the familiarity with the process.

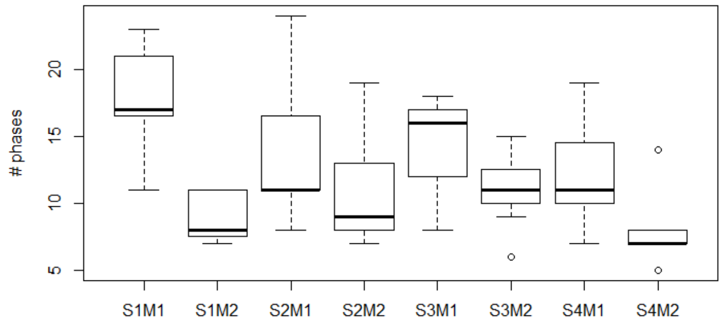
The problem understanding phases are in the first sessions more diffused over the entire modeling process. During the sessions, the problem understanding phases are more shifting towards the first half of the modeling process. Table 14 shows the percentages of problem understanding duration in the first half of the modeling process, compared to the percentages of problem understanding duration in the second half of the modeling process. The modeling time for each model is divided by two and the total problem understanding duration is measured for the first half and the second half of each modeling process. In session 1, 68,63% of the total problem understanding duration is in the first half of the modeling process. 31,37% of the total problem understanding duration is in the second half of the modeling process. In session 4, 76,75% of the problem understanding duration is spent in the first half, 23,28% in the second half. The shift can be caused by a better mental representation of the created model in the first half of the modeling process. Therefore, less number of phases in the problem understanding phase are needed in the second half of the modeling process.

Finding 4: During the sessions, the problem understanding phases are more shifted towards the first half of the modeling process. Indicating that subjects get a better mental representation of the created model at the beginning of the modeling process.

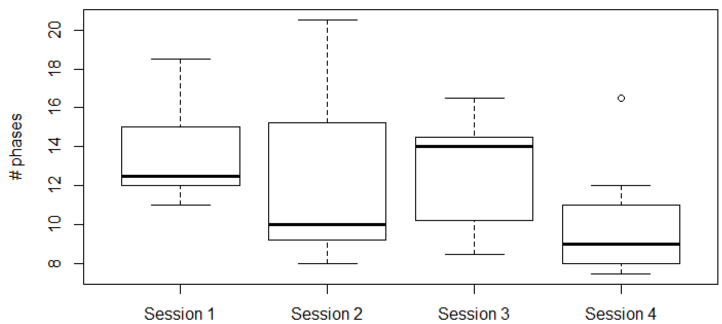
Table 14: Percentages problem understanding duration

	% PU duration first half	% PU duration second half
Session 1	68,63%	31,37%
Session 2	71,01%	28,99%
Session 3	75,91%	24,00%
Session 4	76,75%	23,28%

Figure 27 shows the number of problem understanding phases. The number of phases is considerably higher in S1M1 compared to the other models. As we concluded in section 10.2, this is probably because the modelers have to get used to the modeling task. Also, the number of phases is lower for the second model of each session compared to the first model. Overall, the number of problem understanding phases decreases from an average of 13,7 in session 1 to 10,1 in session 4 where the average number of problem understanding phases is equivalent for the second and third modeling session (12,5). The problem understanding duration (figure 29), decreases from an average of 05:48 minutes in session 1 to 04:14 minutes in session 4. Again the problem understanding duration is considerably longer for S1M1. The second model of each session has a shorter problem understanding duration compared to the first one.



(a) Per model



(b) Per session

Figure 27: Number of problem understanding phases

	min	max	mean	SD
S1M1	11	23	18,0	4,0
S1M2	7	11	9,0	1,9
S2M1	8	24	14,0	5,5
S2M2	7	19	11,0	4,9
S3M1	8	18	14,3	3,7
S3M2	6	15	11,0	2,9
S4M1	7	19	12,3	4,1
S4M2	5	14	8,0	2,8

Table 15: Number of problem understanding phases per model

	min	max	mean	SD
S1	11	18,5	13,7	2,7
S2	8	20,5	12,5	5,0
S3	8,5	16,5	12,6	3,0
S4	7,5	16,5	10,1	3,2

Table 16: Number of problem understanding phases per session

For session 2, 3, and 4 the problem understanding duration remains somewhat equivalent.

Because of the differences between every first and second model, do the subjects also experience the first model description as more difficult compared to the second one? Figure 28 shows the survey answers to the question: 'It was difficult to understand the process.' Figure 28a shows the answers to the first model of each session. Figure 28b shows the answers for the second model of each session. The question is answered on a 5 point Likert scale ranging from completely disagree to completely agree. There are no considerable differences regarding the perceived difficulties between the first and second model for session 1, session 2, and session 3. For session 4 the median score for model 1 is 3,0; the median score for model 2 is 2,0, indicating that the first model was more difficult to understand compared to the second one. Overall, we can conclude that the perceived difficulty does not explain the differences between the first and second model. It seems that the subjects have to get used to the modeling environment, and modeling task every session. Is two models per session the right number of models? What would be the results when subjects had to model three models every session?

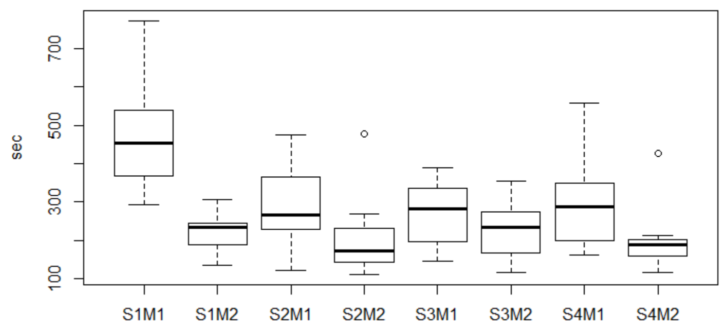
Finding 5: The differences between the first and second model of each session can not be explained by the perceived difficulty to understand the process. It seems that the modelers have to get used to the modeling task every session.

(a) Model 1

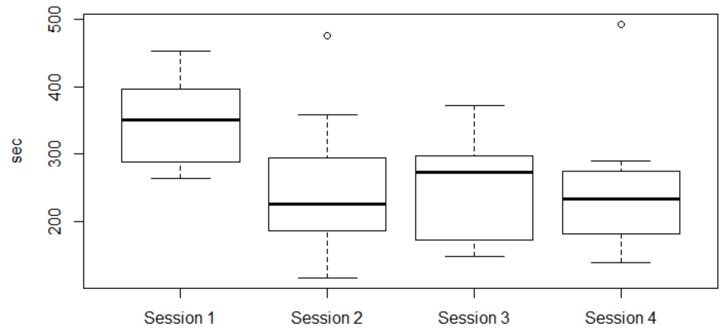
(b) Model 2

Figure 28: Survey answers: It was difficult to understand the process

The duration of the problem understanding phase decreases as well as the average problem understanding duration from session 1 to session 2. From session 2 to session 3, the number of phases is equivalent (12,5), the problem understanding duration remains somewhat the same as well as the average problem understanding duration. From session 3 to session 4, the number of phases decreases, the problem understanding duration remains the same, and the average problem understanding duration increases slightly. Because of the small differences between the sessions, it is not possible to draw any conclusions.



(a) Per model



(b) Per session

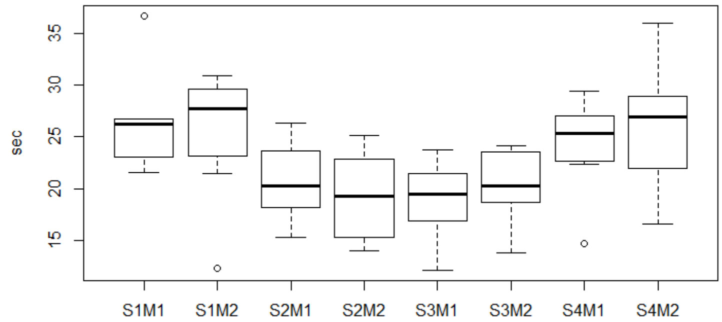
Figure 29: Problem understanding duration

	min	max	mean	SD
S1M1	04:54	12:51	07:57	02:39
S1M2	02:15	05:05	03:40	00:55
S2M1	02:02	07:54	04:53	02:06
S2M2	01:52	07:56	03:36	02:06
S3M1	02:25	06:30	04:29	01:32
S3M2	01:56	05:54	03:47	01:22
S4M1	02:42	09:18	05:00	02:16
S4M2	01:56	07:06	03:28	01:42

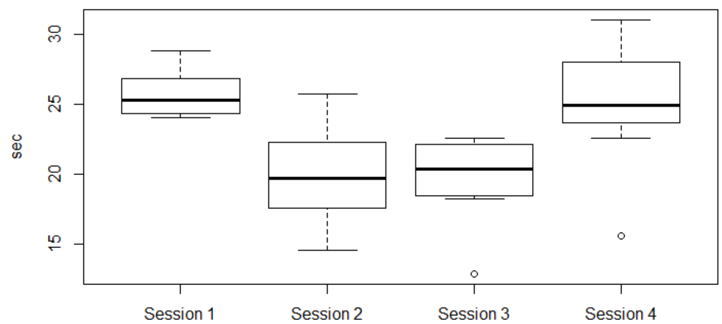
Table 17: Problem understanding duration per model

	min	max	mean	SD
S1	04:25	07:33	05:48	01:12
S2	01:57	07:55	04:14	02:02
S3	02:29	06:12	04:08	01:25
S4	02:19	08:12	04:14	01:57

Table 18: Problem understanding duration per session



(a) Per model



(b) Per session

Figure 30: Average problem understanding duration

	min	**max**	**mean**	**SD**
S1M1	00:22	00:37	00:26	00:05
S1M2	00:12	00:31	00:25	00:07
S2M1	00:15	00:26	00:21	00:04
S2M2	00:14	00:25	00:19	00:04
S3M1	00:12	00:24	00:19	00:04
S3M2	00:14	00:24	00:20	00:04
S4M1	00:15	00:29	00:24	00:05
S4M2	00:17	00:36	00:26	00:07

Table 19: Average problem understanding duration per model

	min	**max**	**mean**	**SD**
S1	00:24	00:29	00:26	00:02
S2	00:15	00:26	00:20	00:04
S3	00:13	00:23	00:20	00:03
S4	00:16	00:31	00:25	00:05

Table 20: Average problem understanding duration per session

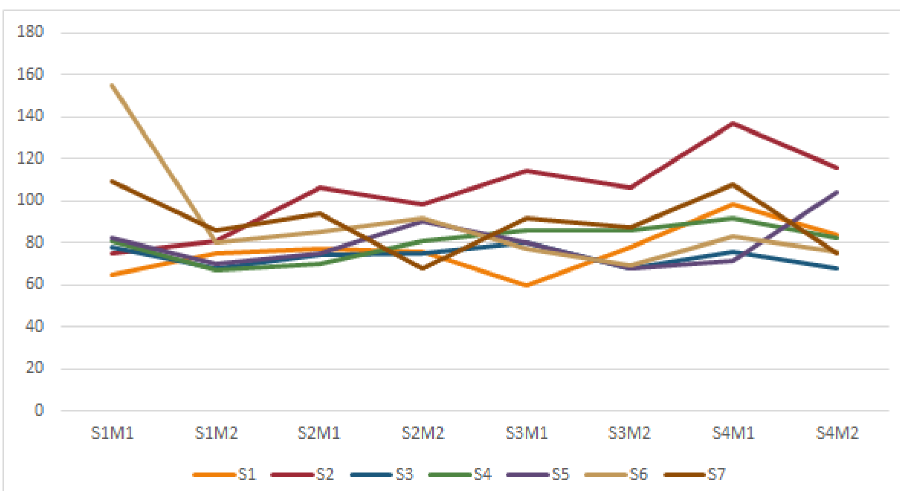
10.4 Modeling/Reconciliation

This section describes the results of the modeling/reconciliation phase. The modeling and reconciliation phases are combined because it is hard to distinguish the modeling and reconciliation phase with the think aloud method. The modeling interactions with CEP are defined in table 4, and table 5. The modeling and reconciliation phase are both parts of the 'carrying out the plan' step according to [Polya, 1957]. Modeling interactions with CEP are interactions where the actual modeling is taking place. Reconciliation actions are used to improve the created model. It is not possible to analyze these phases separately but it is possible to analyze the total number of modeling and reconciliation interactions per model and session.

The number of modeling interactions is, of course, dependent on the model to create. The number of activities, gateways, and conditions affect the number of modeling interactions. Even though we tried to keep the complexity level the same, it may be that the number of modeling interactions, needed to create the model, differs between the models. The modeling interactions are shown in table 21. Figure 31 shows the total number of modeling interactions per subject. As can be seen in figure 31, there is an outlier for subject 6 in S1M1. Subject 2 used overall more modeling actions because the subject modeled the conditions as activities. Table 21 shows the number of modeling interactions without the value of subject 6 in S1M1 and without all values for subject 2. The average values of the number of modeling interactions are between the 74 for S1M2 and 88 interactions for S4M1. The small distribution of the number of modeling interactions can be explained by the fact that we tried to keep the complexity of the models the same.

Finding 6: The number of modeling interactions does not change during the sessions.

Figure 31: *Number of modeling interactions*



[Pinggera, 2014] made a distinction between modelers with a low number of reconciliation interactions and modelers with a high number of reconciliation actions. A high number of reconciliation interactions indicates that the modeler spent a lot of time in a proper layout of the model. A low number of reconciliation actions indicates that the modeler do not care about the layout of the model or they have the skills to model with a proper layout at once. In addition, [Claes et al., 2012b] concluded that frequently moving objects and reshaping is negatively related with the understandability of the model. The reconciliation actions are shown in table 22 and table 23. Figure 32 shows the reconciliation actions per subject.

The number of reconciliation actions is wider distributed compared to the modeling interactions. It stands out that only subject 3 used a small number of reconciliation interactions in all models. Only in S1M1 there is a clear distinction between subjects with a low number of reconciliation actions and subjects with a high number of reconciliation actions. For the other models, this distinction is not clearly visible. The number of reconciliation interactions

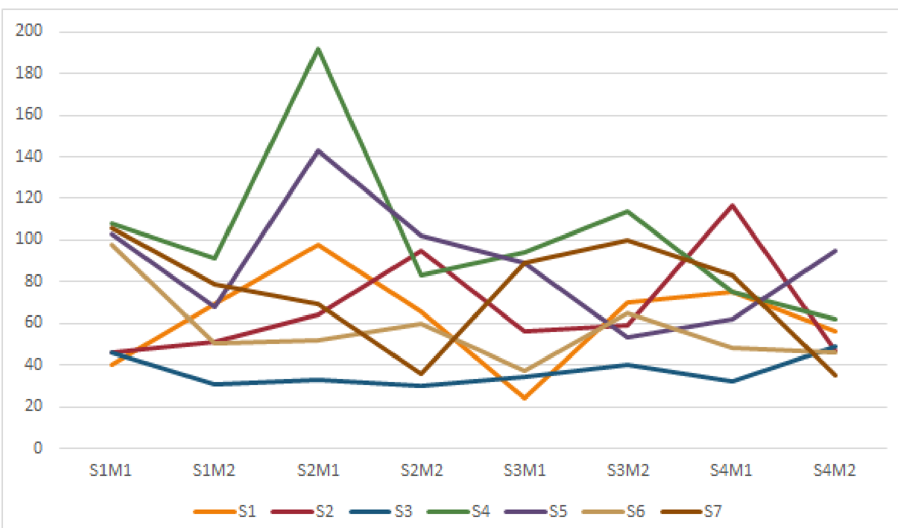
Table 21: Number of modeling interactions

	min	max	mean	SD
S1M1	65	109	83	16,0
S1M2	67	86	74,3	7,5
S2M1	70	94	79,2	8,8
S2M2	68	92	80,3	9,3
S3M1	60	92	79,2	10,8
S3M2	68	87	76	9,0
S4M1	71	108	88	14,0
S4M2	68	104	81,5	12,34

fluctuates strongly. According to the results of this experiment, it is not possible to make a distinction between modelers with a low number of reconciliation interactions and modelers with a high number of reconciliation actions.

Finding 7: The number of reconciliation interactions fluctuates strongly per subject. It is not possible to make a distinction of subjects who do care about the layout and subjects who do not care about the layout.

Figure 32: *Number of reconciliation interactions*



The number of modeling/reconciliation phases decrease during the sessions (figure 33). In session 1, an average of 16 phases is coded. In session 4, an average of 10,4 phases is needed in order to complete the model. The number of modeling/reconciliation phases remains the same for session 2 and session 3. As we saw in previous phases, the number of modeling/reconciliation phases and total duration (figure 34) is smaller for every second model compared to the first one.

The total modeling/reconciliation time slightly decreases from an average of 15:04 minutes in session 1 to 13:03 minutes in session 3. The total modeling/reconciliation duration for session 3 is the same as the duration of session 4.

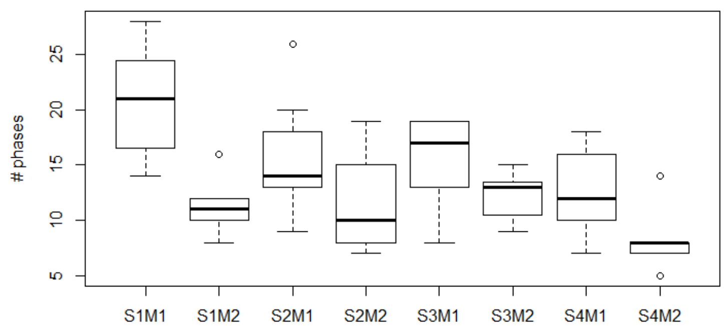
The average modeling/reconciliation duration (figure 35) increases from session 3 to session 4 with 23 seconds

	min	max	mean	SD
S1M1	40	108	78,1	32,1
S1M2	31	91	62,7	20,2
S2M1	33	192	93	56,3
S2M2	30	102	67,4	27,8
S3M1	24	94	60,4	29,9
S3M2	40	114	71,6	26,3
S4M1	32	117	70,3	27,1
S4M2	35	95	55,7	19,3

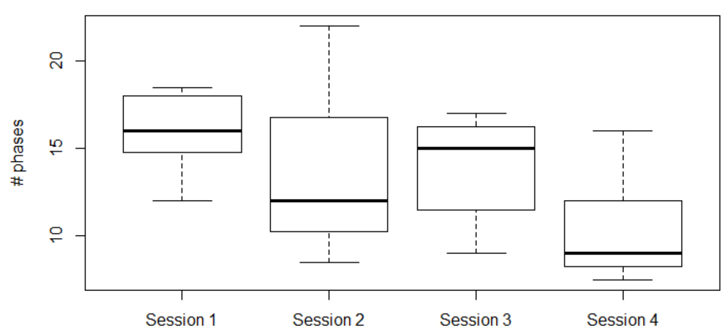
Table 22: Reconciliation interactions per model

	min	max	mean	SD
S1	38,5	99,5	70,4	23,5
S2	31,5	137,5	80,2	38,3
S3	37	104	66	25,1
S4	40,5	82	63	15,34

Table 23: Reconciliation interactions per session



(a) Per model



(b) Per session

Figure 33: Number of modeling/reconciliation phases

	min	max	mean	SD
S1M1	14	28	20,7	5,2
S1M2	8	16	11,3	2,6
S2M1	9	26	15,9	5,6
S2M2	7	19	11,7	4,9
S3M1	8	19	15,4	4,3
S3M2	9	15	12,1	2,2
S4M1	7	18	12,7	4,1
S4M2	5	14	8,1	2,8

Table 24: Number of modeling/reconciliation phases per model

	min	max	mean	SD
S1	12	18,5	16,0	2,4
S2	8,5	22	13,8	5,1
S3	9	17	13,8	3,1
S4	7,5	16	10,4	3,1

Table 25: Number of modeling/reconciliation phases per session

while the average modeling/reconciliation duration for the first three sessions remains somewhat the same.

To summarize: there is a decline in the number of phases. The total modeling duration decrease slightly and the average modeling/reconciliation duration increase from 01:00 minute per phase to 01:23 minutes per phase. These results indicate that modelers create their models with larger chunks of modeling/reconciliation during the sessions. The modeling/reconciliation phase is also less often interrupted by, for example, the problem understanding phase.

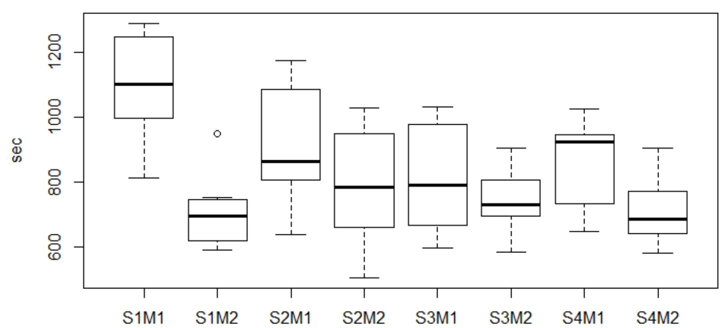
Finding 8: During the sessions, modelers create their models in larger chunks of modeling/reconciliation elements while the total modeling/reconciliation duration decrease. This means that there is less effort needed to create the model.

	min	max	mean	SD
S1M1	13:33	21:29	18:19	02:56
S1M2	09:52	15:50	11:50	02:04
S2M1	10:40	19:36	15:23	03:17
S2M2	08:26	17:08	13:12	03:16
S3M1	09:58	17:12	13:35	03:02
S3M2	09:46	15:05	12:27	01:46
S4M1	10:47	17:06	14:11	02:28
S4M2	09:42	15:05	11:55	01:59

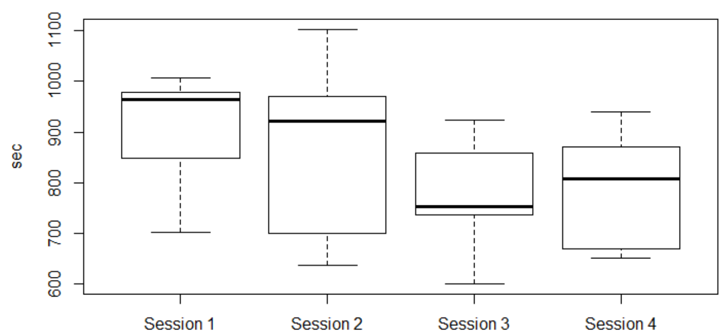
Table 26: Modeling/reconciliation duration per model

	min	max	mean	SD
S1	11:43	16:47	15:04	01:57
S2	10:37	18:22	14:17	02:59
S3	10:01	15:23	13:01	01:50
S4	10:51	15:39	13:03	02:04

Table 27: Modeling/reconciliation duration per session

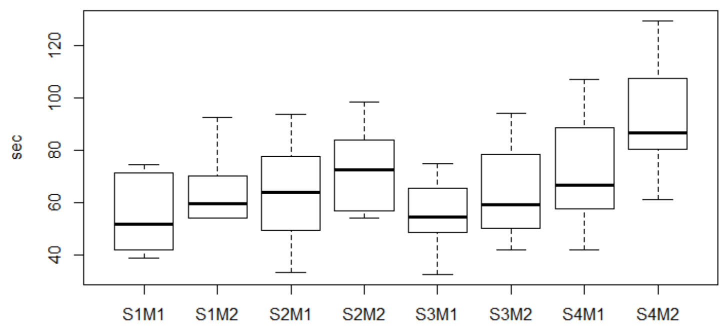


(a) Per model

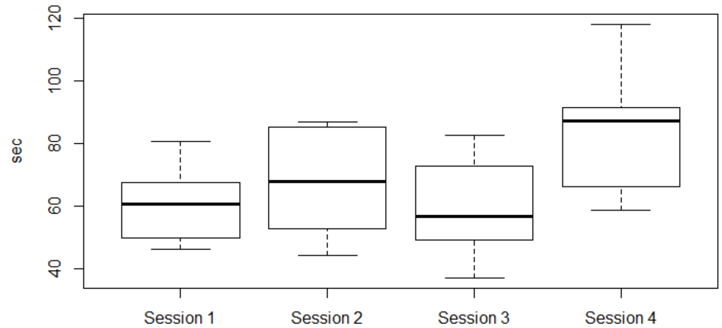


(b) Per session

Figure 34: Modeling/reconciliation duration



(a) Per model



(b) Per session

Figure 35: Average modeling/reconciliation duration

	min	max	mean	SD
S1M1	00:39	01:14	00:56	00:16
S1M2	00:54	01:33	01:05	00:15
S2M1	00:33	01:34	01:04	00:22
S2M2	00:54	01:38	01:12	00:17
S3M1	00:32	01:15	00:56	00:15
S3M2	00:42	01:34	01:05	00:21
S4M1	00:42	01:47	01:12	00:23
S4M2	01:01	02:09	01:33	00:23

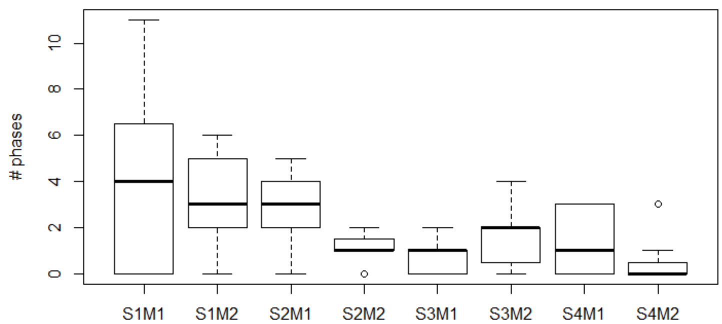
Table 28: Average modeling/reconciliation duration per model

	min	max	mean	SD
S1	00:46	01:21	01:00	00:13
S2	00:44	01:27	01:08	00:18
S3	00:37	01:23	01:00	00:17
S4	00:59	01:58	01:23	00:21

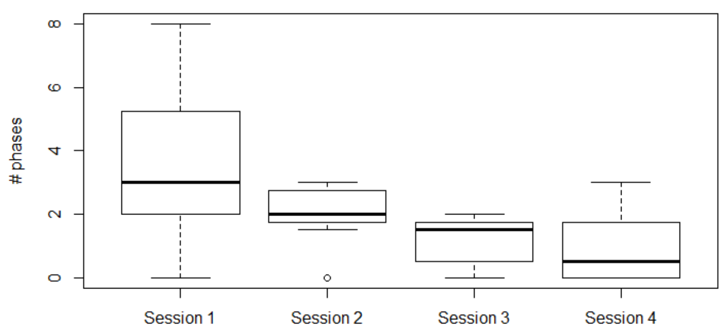
Table 29: Average modeling/reconciliation duration per session

10.5 Method Finding

The method finding phase was sometimes hard to distinguish from the modeling/reconciliation phase. More information about this is explained in the general findings section. The verbal utterances are coded as the method finding phase when the subject thought about the possible modeling options to translate the textual description into BPMN elements, without any interactions with the modeling environment.



(a) Per model



(b) Per session

Figure 36: Number of method finding phases

The method finding phase is not often coded. One subject (subject 3), did not verbalized any thoughts in the method finding phase. The other six subjects uttered between the 8 and 25 method finding phases in total. Figure 36 shows the distribution of the number of method finding phases during the modeling sessions. Because one subject does not use the method finding phase at all, the minimum value is always 0 in the tables.

Figure 36 shows the number of method finding phases per model (a) and per session (b). The number of method finding phases decreases during the sessions from an average value of 3,6 to an average value of 1,0. The method finding duration (figure 37) also decreases from an average of 01:28 minutes in session 1 to 00:17 minutes in session 4.

Finding 9: The number of method finding phases, the total duration of the method finding, and the average duration decrease during the sessions.

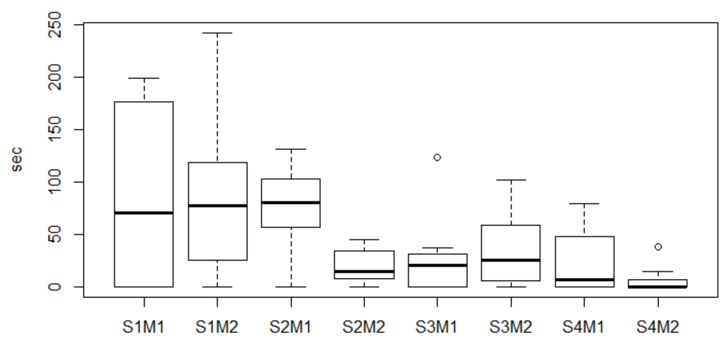
The subjects gain more and more knowledge about the modeling language, which means that they have to think

	min	max	mean	SD
S1M1	0	11	4,0	4,4
S1M2	0	6	3,3	2,2
S2M1	0	5	2,9	1,7
S2M2	0	2	1,1	0,7
S3M1	0	2	0,7	0,8
S3M2	0	4	1,6	1,4
S4M1	0	3	1,4	1,5
S4M2	0	3	0,6	1,1

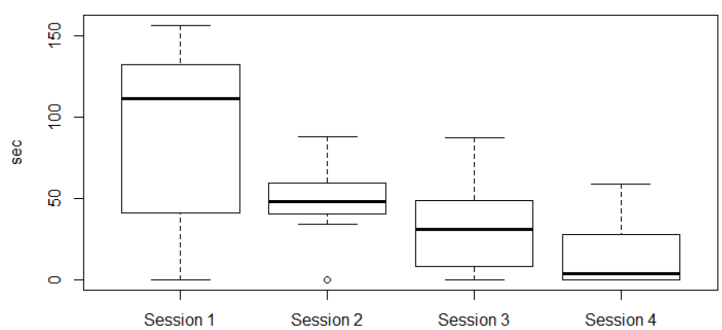
Table 30: Number of method finding phases per model

	min	max	mean	SD
S1	0	8	3,6	2,7
S2	0	3	2,0	1,0
S3	0	2	1,1	0,8
S4	0	3	1,0	1,2

Table 31: Number of method finding phases per session



(a) Per model



(b) Per session

Figure 37: Method finding duration

	min	max	mean	SD
S1M1	00:00	03:19	01:29	01:33
S1M2	00:00	04:02	01:26	01:24
S2M1	00:00	02:11	01:16	00:43
S2M2	00:00	00:45	00:20	00:18
S3M1	00:00	02:03	00:29	00:44
S3M2	00:00	01:42	00:37	00:38
S4M1	00:00	01:19	00:26	00:32
S4M2	00:00	00:38	00:07	00:14

Table 32: Method finding duration per model

	min	max	mean	SD
S1	00:00	02:36	01:28	01:02
S2	00:00	01:28	00:48	00:27
S3	00:00	01:27	00:33	00:31
S4	00:00	00:59	00:17	00:22

Table 33: Method finding duration per session

less about the possible modeling options. Does the knowledge of the modeling language affects the method finding phase? We analyzed the answers given in the surveys for two statements. (1) I am familiar with BPMN models (figure 38, table 34). (2) I find it easy to translate a description of a process into a process model (figure 39, table 35). The subjects become more and more familiar with BPMN models during the sessions. Table 34 shows that the value increase form 3,1 in session 1, to 4,3 in session 2. The perceived easiness to create a BPMN model increases as well from 2,7 in session 1 to 3,6 in session 2. These results confirm that the method finding phase is dependent on familiarity with BPMN models and the easiness to translate a description of a process into a process model.

Finding 10: When subjects become more familiar with the modeling language, the number of verbal utterances and the duration in the method finding phase decreases.

Figure 38: *Survey answers: I am familiar with BPMN models*

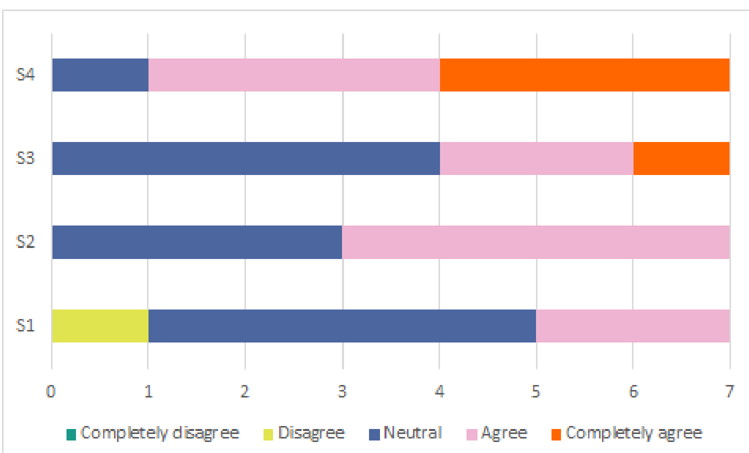


Table 34: Survey answers: I am familiar with BPMN models

	min	max	mean
S1	2	4	3,1
S2	3	4	3,6
S3	3	5	3,6
S4	3	5	4,3

Figure 39: *Survey answers: I find it easy to translate a description of a process into a process model*

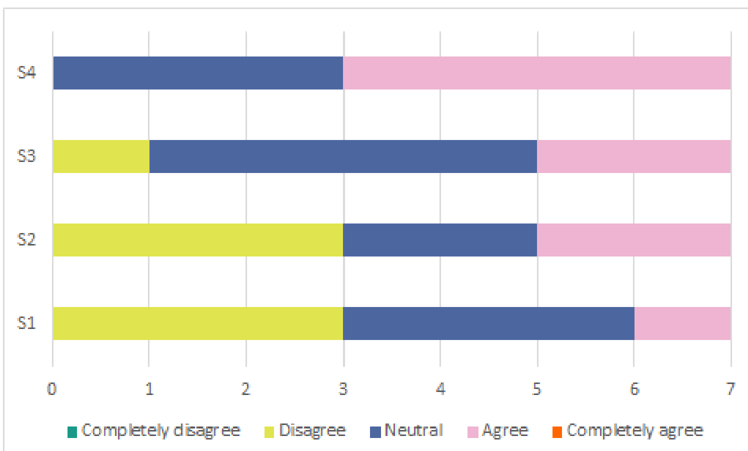
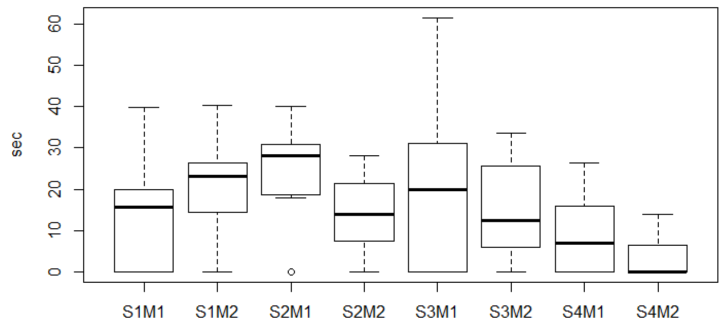
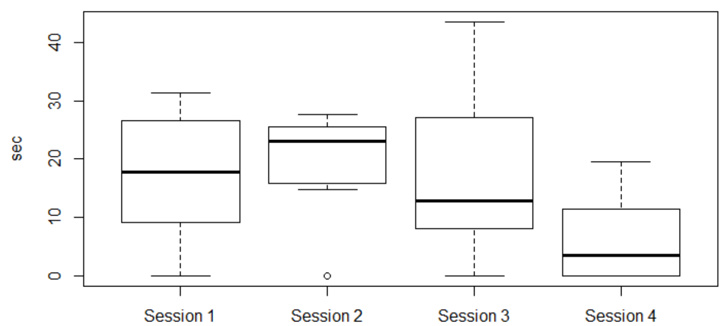


Table 35: Survey answers: I find it easy to translate a description of a process into a process model

	min	max	mean
S1	2	4	2,7
S2	2	4	2,9
S3	2	4	3,1
S4	3	4	3,6



(a) Per model



(b) Per session

Figure 40: Average method finding duration

	min	max	mean	SD
S1M1	00:00	00:40	00:14	00:15
S1M2	00:00	00:40	00:21	00:13
S2M1	00:00	00:40	00:24	00:13
S2M2	00:00	00:28	00:14	00:10
S3M1	00:00	01:01	00:21	00:23
S3M2	00:00	00:34	00:16	00:13
S4M1	00:00	00:26	00:09	00:10
S4M2	00:00	00:14	00:04	00:07

Table 36: Average method finding duration per model

	min	max	mean	SD
S1	00:00	00:31	00:17	00:12
S2	00:00	00:28	00:19	00:10
S3	00:00	00:44	00:18	00:15
S4	00:00	00:20	00:07	00:08

Table 37: Average method finding duration per session

10.6 Validation

In the validation phase, the modeler checks the created model for any mistakes. Just like the method finding phase, the validation phase is more difficult to analyze compared to the problem understanding and modeling/reconciliation phases. In the validation phase, we have no additional information because there are no modeling interactions with the modeling environment. The validation phase is harder to analyze because it is closely linked to the problem understanding phase and to the modeling/reconciliation phase. More information about these difficulties is explained in section 10.7. We coded the verbal utterances as the validation phase when the subject explicitly uttered that he or she is going to check the model.

One subject did not verbalized any utterances linked to the validation phase. That is why all minimum values in the tables in this section are 0. Two subjects verbalized validation utterances in one model. Three subjects verbalized validation utterances distributed over four models. Only one subject checked every created model.

In session 4, only subject 6 checked the created models. The values of S4M1 and S4M2 are thus based on one participant. In S1M1, 4 subjects spent some time in the validation phase. The other values are shown in table 38. The number of subjects who used the validation phase decreases during the modeling sessions.

Table 38: Number of subjects who used the validation phase per model

	# subjects
S1M1	4
S1M2	4
S2M1	3
S2M2	3
S3M1	3
S3M2	3
S4M1	1
S4M2	1

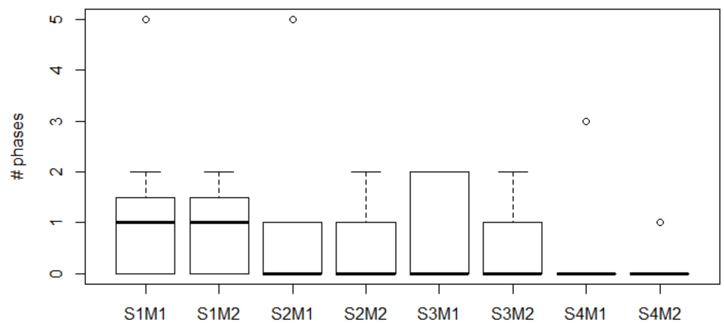
Finding 11: The number of subjects who verbalized utterances in the validation phase decreases during the session from 4 subjects in session 1 to 1 subject in session 4.

Is it possible to draw any conclusions about the number of validation phases and duration, because of the small number of subjects who verbalized any utterances in the validation phase? The number of validation phases are shown in figure 41. The validation duration is shown in figure 42 where the validation phase for subject 6 is detected as an outlier. The number of validation phases decreases as well as the validation duration. However, because of the small number of subjects, we will not draw any conclusions.

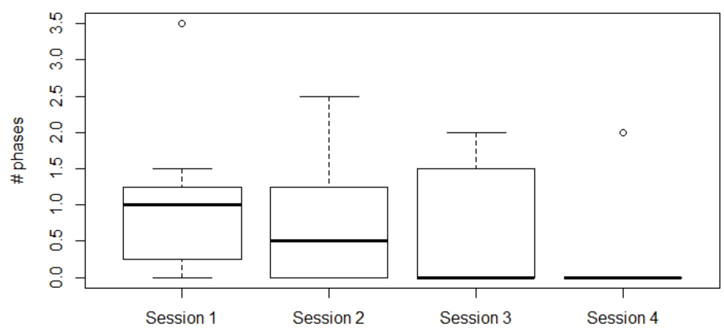
It is more interesting to investigate when subjects check (parts of) the created model. Subject 6 always checked the created model independent of the perceived difficulty to create the model. We coded the validation phase for subject 1 only in S1M1. Subject 1 used the validation phase twice in the most difficult model. For the other four subjects, there is no relation between coded validation phases and the perceived difficulty to create the process model. For three subjects, the validation phases are randomly distributed over the eight models. Subject 3 checked the created models only in the first two sessions for a short period of time.

It seems that for subject 6, checking the created model is part of the used strategy. For subject 3, it was no longer necessary to check the created models in session 3 and session 4. For the other subjects it is hard to explain whether or not using the validation phase.

Finding 12: It is hard to explain when subjects used the validation phase to check (parts of) the created models. Only one modeler always checked the created models at the end of the process.



(a) Per model



(b) Per session

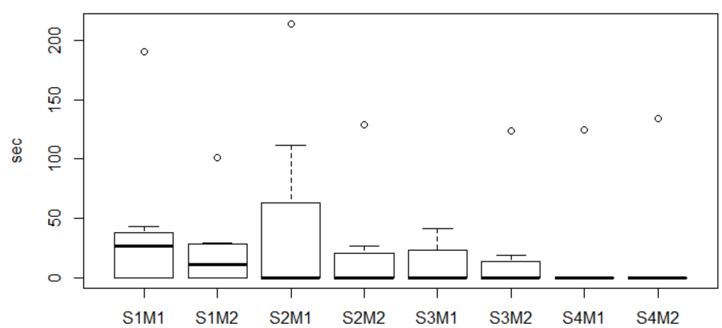
Figure 41: Number of validation phases

	min	max	mean	SD
S1M1	0	5	1,3	1,8
S1M2	0	2	0,9	0,9
S2M1	0	5	1,0	1,8
S2M2	0	2	0,6	0,8
S3M1	0	2	0,9	1,1
S3M2	0	2	0,6	0,8
S4M1	0	3	0,4	1,1
S4M2	0	1	0,1	0,4

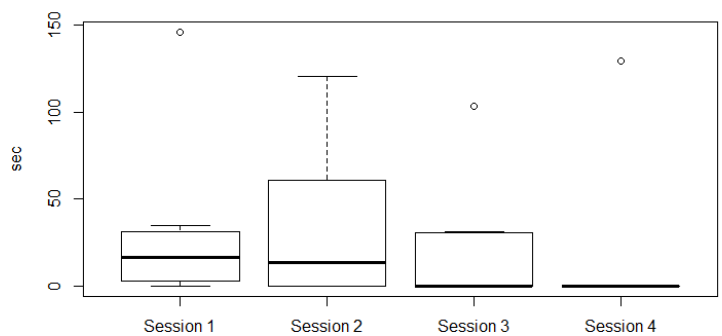
Table 39: Number of V phases per model

	min	max	mean	SD
S1	0	3,5	1,1	1,2
S2	0	2,5	0,8	1,0
S3	0	2	0,7	0,9
S4	0	2	0,3	0,8

Table 40: Number of V phases per session



(a) Per model



(b) Per session

Figure 42: Total validation duration

	min	max	mean	SD
S1M1	00:00	03:11	00:42	01:08
S1M2	00:00	01:41	00:24	00:36
S2M1	00:00	03:34	00:49	01:24
S2M2	00:00	02:09	00:24	00:47
S3M1	00:00	01:23	00:25	00:34
S3M2	00:00	02:04	00:22	00:46
S4M1	00:00	02:05	00:18	00:47
S4M2	00:00	02:14	00:19	00:51

Table 41: Validation duration per model

	min	max	mean	SD
S1	00:00	02:26	00:33	00:52
S2	00:00	02:00	00:37	00:53
S3	00:00	01:43	00:23	00:38
S4	00:00	02:09	00:19	00:49

Table 42: Validation duration per session

10.7 General findings

Besides the results per phase, there are some general findings we want to discuss in this section. Section 10.7.1 describes the combination of the method finding phase with the modeling/reconciliation phase. The combination of the validation phase with the modeling/reconciliation phase is described in section 107.2.

10.7.1 Method finding in combination with modeling/reconciliation

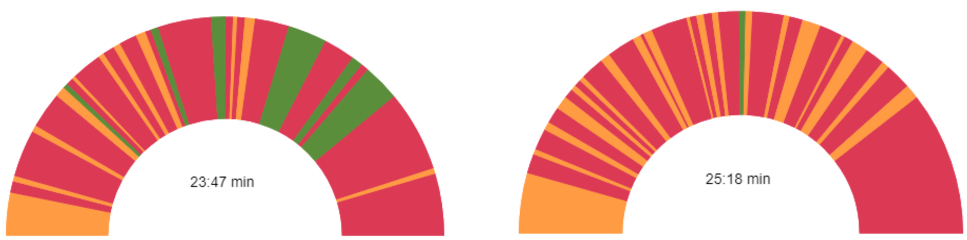
we have not seen many method finding phases because method fining and modeling/reconciliation often take place simultaneously. That is why the method finding phase is sometimes hard to distinguish from the modeling/reconciliation phase.

In some cases, the modeler first thinks about the possible modeling options, before one of the options is implemented on the modeling canvas. An example is shown in figure 90a. An example of a verbal utterance in the method finding phase:

Dus dan krijg je eigenlijk een soort ehm ja ik denk loop eigenlijk. Ik weet niet hoe ik dat ga doen. Moet ik dat met een ander ding doen? Ik denk het wel. Eeehmm contact opnemen klant, ja.

In other cases, modelers think about the possible modeling options while they model these options right afterwards. We coded these interactions as the modeling/reconciliation phase (figure 90b). This finding explains the relatively few number of method finding phases. An example of a verbal utterance where method finding takes place simultaneously as modeling/reconciliation:

Inspecteren hypotheek. Dan zou ik hier weer een OR doen omdat je die 1 miljoen hebt en niet die 1 miljoen. Oke en dan heb je hier komen er twee dingen uitfi



(a) Subject 1, Session 1, Model 2 (b) Subject 5, Session 2, Model 2

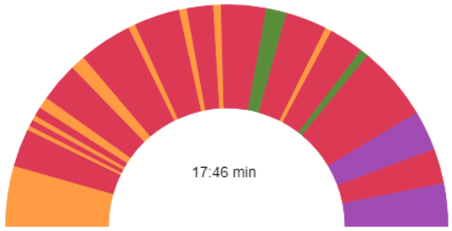
Figure 43: Example method finding and modeling/reconciliation

10.7.2 Validation in combination with modeling/reconciliation

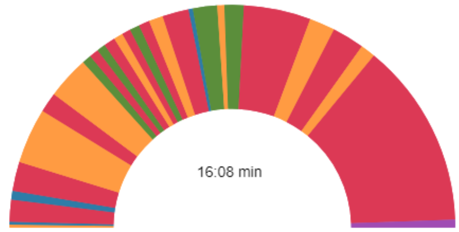
Just like the method finding phase, the validation phase is sometimes blended with the modeling/reconciliation phase in two ways.

The first one is when modelers check the created models in the validation phase and some mistakes are found. The validation phase is then followed by a problem understanding, method finding, or modeling/reconciliation phase. When no mistakes are found, the subject continues with the process of process modeling or the process ends. There are 40 validation phases in total. 28 transitions are starting from the validation phase. 12 validation phases are coded at the end of the process which means that no other phase will follow. 21 transitions, starting from the validation phase, go to the modeling/reconciliation phase. 7 of them go to the problem understanding phase. An example is given in figure 91a.

The first validation phase is followed by a modeling/reconciliation phase. The subject checked the created model in the validation phase, found mistakes, correct the mistakes in the modeling/reconciliation phase, and then continues with validating the model.



(a) Example 1



(b) Example 2

Figure 44: Example method validation and modeling/reconciliation

Oke, terug naar het begin ... Ooh wacht het kan natuurlijk allebei gebeuren ... (Validation)

... dus dan is het, proces wordt dan gesplitst met goederen die wel nodig zijn, die worden verpakt en gaat het door ... (modeling/reconciliation)

... Dat klopt, en dan is het voertuig huren en ontvangen wegenkaart en op zoek naar accommodatie ... (validation)

The phases followed by a validation phase are coded as problem understanding or modeling/reconciliation but may be part of the validation phase.

The second form is when modelers start with modeling all the activities and model the sequence flows between the activities and gateways at the end of the modeling process. When they are modeling the sequence flows, they check the model they made at the same time. We coded these verbalizations again as the modeling/reconciliation phase. An example is given in figure 91b.

... Dan ga ik nu alle pijlen neerzetten, heel veel pijlen ...

10.8 Discussion

This section shows the findings of creating 8 business process models from an informal textual description of a process of 7 participants during 4 sessions. Each session consists of two modeling tasks. Section 10.8.1 describes the findings for every modeling phase.

10.8.1 Findings

Table 49 gives an overview of the findings per phase for this experiment. Overall, fewer phases are needed to create the process models which results in less transitions between the different phases. [Martini et al., 2016] found that inexperienced modelers needed significantly more time compared to experienced modelers. [Batra and Davis, 1992] investigates the similarities and differences between novel and expert modelers for a conceptual data modeling task and found no differences in modeling time between novel and expert modelers. We found a minor decrease in the modeling duration. Are the subjects, participating in this experiment, experienced modelers? It is hard to define a classification between inexperienced and experienced modelers.

In the problem understanding phase, we found that whether or not reading the textual description first is dependent of the used strategy. During the sessions, the problem understanding phase is more shifted towards the first half of the process of process modeling. This shift can be caused by changing modeling strategies or that the subjects become better in recognizing modeling patterns stored in long term memory (chapter 4). It seems that modelers have to get used to the modeling environment every session. What does this mean for the experiments done in the past where participants had to model one process model?

In the modeling/reconciliation phase, the modeling interactions differ slightly. We tried to keep the complexity level the same with some small differences between the models. [Pinggera et al., 2015] identified different modeling styles (section 6.3). Modeling with high efficiency, modeling emphasizing a good layout and modeling that is neither efficient nor focused on layout. In contrast to the modeling interactions, the reconciliation interactions fluctuates strongly per subject. Therefore, it is not possible to make a distinction between modelers who do care about the layout of the process models and subjects who do not care about the layout of the process models. overall, the subjects create the models in larger chunks of modeling/reconciliation during the sessions indicating that less switching is needed between the other phases.

The number of method finding phases, the total duration of the method finding and the average duration decrease during the sessions. This indicates that the modelers are more familiar with process modeling. The use of the method finding phase is also dependent of the personality of the modeler [Pinggera, 2014] (section 7.2.5) and the method finding phase is sometimes blended with the modeling/reconciliation phase (section 11.6)

The number of subjects who verbalized utterances in the validation phase decreases during the sessions. It is hard to explain when the subjects check their created model. As we have explained in the previous section, the validation phase is sometimes blended with the modeling/reconciliation phase. We coded these verbalizations as the modeling/reconciliation phase.

10.9 Conclusion

It is now possible to answer SQ4.3 and SQ4.4

SQ4.3: Does the number of modeling phases change during the sessions?

The total number of modeling phases decrease during the sessions. We identified a small decrease in the problem understanding phases. The number of modeling/reconciliation phases decreases more, compared to the number of problem understanding phases. We identified a decrease of the number of method finding and validation phases as well. Although, the method finding phase and validation phase is harder to analyze because these phases are sometimes blended with the modeling/reconciliation phase.

SQ4.4 Does the duration of modeling phases change during the sessions?

Table 43: Overview findings per phase

Finding	Phase	
Finding 1	all	During the sessions, fewer phases are needed to create the process model. Fewer phases result in fewer transitions which indicate that less switching between phases is needed to complete the process model.
Finding 2	all	There is a decrease in modeling duration, with an outlier for the first created model. This can be caused by the fact that modelers have to get used to the modeling environment, and the problem solving task.
Finding 3	Problem understanding	Whether or not reading the whole textual description first is dependent on the used strategy and independent of the familiarity with the process.
Finding 4	Problem understanding	During the sessions, the problem understanding phases are more shifted towards the first half of the modeling process. Indicating that subjects get a better mental representation of the created model in the first half of modeling process.
Finding 5	Problem understanding	The differences between the first and second model of each session can not be explained by the perceived difficulty to understand the process. It seems that the modelers have to get used to the modeling task every session.
Finding 6	Modeling/ reconciliation	The number of modeling interactions does not change during the sessions
Finding 7	Modeling/ reconciliation	The number of reconciliation interactions fluctuates strongly per subject. It is not possible to make a distinction of subjects who do care about the layout and subjects who do not care about the layout.
Finding 8	Modeling/ reconciliation	During the sessions, modelers create their models in larger chunks of modeling/reconciliation element while the total modeling/reconciliation duration decrease. This means that there is less effort needed to create the model.
Finding 9	Method finding	The number of method finding phases, the total duration of the method finding, and the average duration decrease during the sessions.
Finding 10	Method finding	When subjects become more familiar with the modeling language, the number of verbal utterances and the duration in the method finding phase decreases.
Finding 11	Validation	The number of subjects who verbalized utterances in the validation phase decreases during the session from 4 subjects in session 1 to 1 subject in session 4.
Finding 12	Validation	It is hard to explain when subjects used the validation phase to check (parts of) the created models. Only one modeler always checked the created models at the end of the process.

The modeling duration decreases during the sessions with an average of 05:00 minutes. The duration of the problem understanding phase decreases between session 1 and session 2. After these sessions, the problem understanding duration remains the same. The modeling/reconciliation duration decreases until session 3. The modeling duration is equal for session 3 and session 4. The duration of the method finding and validation phases decreases during the sessions.

11 Conclusions and future work

We will finish this thesis with a summary of the conclusions and suggestions for future work. Section 12.1 gives a summary of the answers to the research questions. Section 12.2 gives some suggestions for future research.

11.1 Conclusion

The aim of this thesis is to investigate the process of process modeling in a qualitative, longitudinal modeling experiment. According to the literature, the process of process modeling can be seen as a problem solving task. [Polya, 1957] defined four problem solving steps: understanding the problem, devising a plan, carrying out the plan, and looking back to check the results. The problem solving steps can be translated into five steps in process modeling: problem understanding, method finding, modeling, reconciliation, and validation.

To analyze the different modeling phases in a modeling task, we used CEP and the think aloud method. CEP is a tool that supports modeling experiments. With CEP, it is possible to analyze the modeling and reconciliation phase. We used the think aloud method as an additional method to analyze the problem understanding, method finding, and validation phase.

Different factors affect the process of process modeling. These factors are divided into task specific factors, and modeler specific factors. Examples of task specific factors are complexity level, layout of the textual description, and modeling language. Examples of modeler specific factors are working memory, modeling expertise, level of motivation, process knowledge, and the personality of the modeler.

Different strategies are detected for translating a description of a process into a process model. According to the results, 6 modeling strategies are distinguished. Some modelers read the whole textual description first. Others start with modeling immediately. Some modelers modeled step by step. Other subjects modeled the activities and gateways first and modeled the sequence flows at the end of the process. 3 subjects changed their strategy during the sessions. 4 subjects used the same strategy during the modeling sessions.

The problem understanding phase, and modeling/reconciliation phase are the most frequently coded phases. Furthermore, most of the transitions starting in the problem understanding phase go to the modeling/reconciliation phase and from the modeling/reconciliation phase to the problem understanding phase.

The total number of modeling phases decreases, as well as the modeling duration. It seems that the modelers have to get used to the modeling environment and the problem solving task every session. The number of reconciliation actions fluctuates strongly per subject. Therefore, it is not possible to make a distinction of subjects who do care about the layout of the model and subjects who do not care about the layout of the models. When subjects become more familiar with process modeling, the number of method finding phases and the duration of the method finding phase decrease. The number of subjects who verbalized any utterances in the validation phase is low. It is hard to explain when subjects used the validation phase to check the created model. Only one subject checked always the created models and performed best at the exam.

In addition, the method finding phase and the validation phase are sometimes blended with the modeling/reconciliation phase. These phases are coded as the modeling/reconciliation phase. This can cause the relatively low number of method finding and validation phases.

11.2 Future work

This section explains some suggestions for future research.

Eye tracking In this research, we only used the think aloud method together with CEP. In the future, it would be valuable to combine this with, for example, eye tracking. With eye tracking, more information about the cognitive effect on process modeling can be obtained. Another advantage of using this method is the possibility to investigate data of more participants since the think aloud method is a time consuming process. With a very good eye tracker, it would also be possible to investigate which signal words in the textual description are relevant for which part of the process model.

Novel and experts Due to time restrictions, it was not possible to compare novel with expert modelers. What are the differences between novel and expert process modelers? What is the difference in the used strategy? Do novel process modelers need more time to complete the model compared to expert modelers? Do expert modelers store information about modeling patterns in schemas as we saw with chess players?

Quality models Does the strategy used influence the quality of the created models? Different types of frameworks exist to determine the quality of the created model. Which strategy leads to a better model?

Coding per sentence In this thesis, a threshold of five seconds is used to detect different phases. What would be the effect when coding the verbal utterances per sentence? Now, the method finding phase, and the validation phase are sometimes blended with the modeling/reconciliation phase. Is this problem solved when coding the verbal utterances per sentence?

Three models The results show that the number of phases and the duration of modeling is higher for every first model compared to the second model in each session. It seems that the modelers have to get used to the modeling environment every session. What would happen when the modelers have to create three models?

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Appendices

A Consent form

CONSENT FORM FOR RESEARCH PARTICIPATION

Research Team

Principle investigator: Jan Martijn van der Werf (j.m.e.m.vanderwerf@uu.nl),
Researchers involved: Maud Stigter (m.p.b.stigter@students.uu.nl), Robert Evertse (r.evertse@students.uu.nl)

Research description

In this research, we want to investigate the learning curve in process modeling strategies of inexperienced modelers.

Your task is to create two BPMN models from a textual process description. Each session consists of two surveys and two modeling tasks. There are four sessions in total. Subjects need to verbalize their thoughts while creating these models. The verbalizations are recorded and transcribed.

Consent

- I have read this document, and the research study has been explained to me. I have been given the opportunity to ask questions, and my questions have been answered. If I have additional questions, I have been told whom to contact.
- I understand that it is at all times possible to retract myself from the experiment.
- I understand that the results of this experiment will not be used for grading the course Informatiesystemen
- I agree that the created models will be used in research, can be shared with other researchers, and can be made publicly available, provided that the document is anonymized.
- I agree that the audio recordings will be used only by researchers of Utrecht University, and that the audio recordings will be transcribed. Only the transcriptions can be shared with other researchers, or made publicly available, provided that the transcription is anonymized. As soon as the audio recordings are transcribed, they will be deleted.

In addition:

- Any personal information that could reasonably identify you will be removed or changed before files are shared with other researchers or results are made public.
- The principal investigator will keep a link that identifies you to your coded information, but this link will be kept secure and available only to the principal investigator or selected members of the research team. Any information that can identify you will remain confidential.
- The information in this study will only be used in ways that will not reveal who you are. You will not be identified in any publication from this study or in any data files shared with other researchers. Your participation in this study is confidential.

By signing the form, I agree upon to participate in the research study described above and will receive a copy of this consent form.

Name: ______________________________ Date: ___________________________

Signature: ______________________________

B Session 1

B.1 Instruction form

Proces modelleren met think aloud

Je doet mee aan een masteronderzoek waarbij het proces van modelleren wordt onderzocht in 4 modelleersessies. Per sessie worden er twee BPMN modellen getekend met behulp van Cheetah Experimental Platform en think aloud. In totaal zijn er 4 sessies gedurende het vak.

Cheetah Experimental Platform (CEP)

CEP is een tool wat het modelleren van BPMN processen ondersteunt. Ook is het mogelijk om een vragenlijst toe te voegen in CEP. We gebruiken alleen de onderdelen van BPMN die jullie in college geleerd hebben.

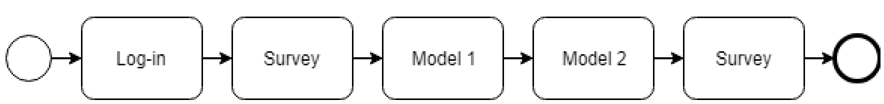
Think aloud

Think aloud wordt gebruikt om je gedachtes te analyseren wanneer je bezig bent met het maken van een model. Dit kan gebruikt worden om de verschillende strategieën voor het maken van een model te onderscheiden. Jullie gedachtes worden opgenomen en kunnen daardoor later geanalyseerd worden. Wat is precies de bedoeling van think aloud:

- Het is de bedoeling dat je al je gedachtes hardop uitspreekt wanneer je bezig bent met het maken van een model. Blijf alles wat in je gedachte opkomt uitspreken gedurende het gehele experiment.
- Je mag in het Nederlands spreken.
- Tijdens het modelleren is het niet mogelijk om vragen te stellen. Ik zal alleen het proces onderbreken om te wijzen op het blijven uitspreken van je gedachtes waar nodig.

Uitvoering experiment

Tijdens elke modelleersessie werk je aan twee modellen. De sessie zal beginnen met een korte vragenlijst, gevolgd door twee modelleertaken. De sessie zal ook weer eindigen met een korte vragenlijst.



Laat je niet uit de weg slaan door de complexiteit van de modellen. Zie het als een uitdaging om het model zo goed mogelijk te maken. Je mag alle tijd nemen voor het maken van de modellen. Vergeet niet om al je gedachtes hardop en duidelijk uit te spreken.

B.2 Survey

Survey sessie 1

Vragen vooraf

1. Welke studie volg je?
2. Hoe vaak heb je het vak informatiesystemen gevolgd? 1^{e} keer 2^{e} keer 3^{e} keer

3. Ik ben goed bekend met procesmodellen 1 2 3 4 5
4. Ik kan procesmodellen makkelijk lezen 1 2 3 4 5
5. Ik kan procesmodellen makkelijk maken aan de hand van een procesbeschrijving 1 2 3 4 5
6. Ik vind mezelf een expert in het maken van procesmodellen 1 2 3 4 5
7. Ik ben goed bekend met BPMN modellen 1 2 3 4 5
8. Ik kan BPMN modellen makkelijk lezen 1 2 3 4 5
9. Ik kan BPMN modellen makkelijk maken aan de hand van een procesbeschrijving 1 2 3 4 5
10. Ik vind mezelf een expert in het maken van BPMN modellen 1 2 3 4 5

11. Ik ben bekend met het aanvraagproces van een hypotheek 1 2 3 4 5
12. Ik ben bekend met de taken van een piloot voorafgaand aan een vlucht 1 2 3 4 5

Vragen achteraf

1. Ik vond de beschrijving van proces 1 duidelijk 1 2 3 4 5
2. Ik vond de beschrijving van proces 2 duidelijk 1 2 3 4 5
3. Ik vond proces 1 moeilijk te begrijpen 1 2 3 4 5
4. Ik vond proces 2 moeilijk te begrijpen 1 2 3 4 5
5. Ik vond het maken van BPMN model 1 moeilijk 1 2 3 4 5
6. Ik vond het maken van BPMN model 2 moeilijk 1 2 3 4 5
7. Ik vond het maken van BPMN model 1 makkelijk 1 2 3 4 5
8. Ik vond het maken van BPMN model 2 makkelijk 1 2 3 4 5
9. Ik vind mezelf een expert in het maken van procesmodellen 1 2 3 4 5
10. Ik vind mezelf een expert in het maken van BPMN modellen 1 2 3 4 5

11. Algemene opmerkingen model 1
12. Algemene opmerkingen model 2

B.3 Model description 1 Session 1

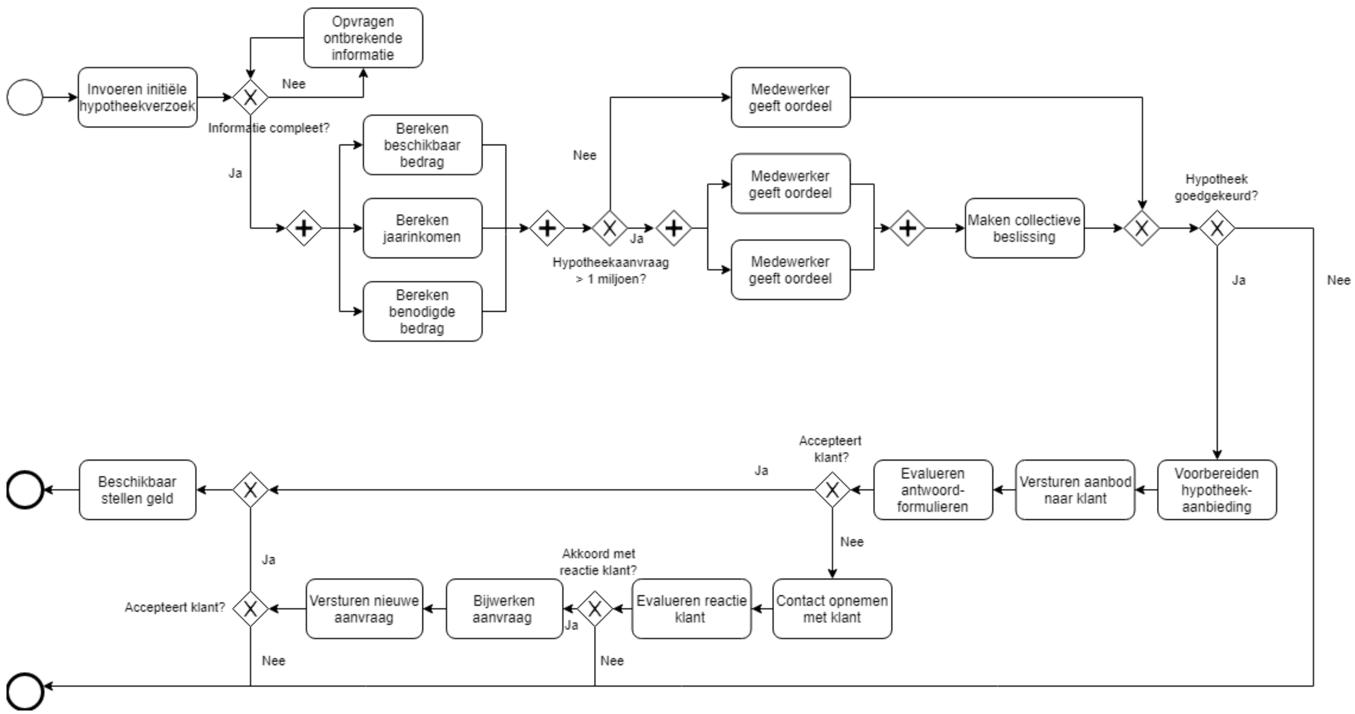
Beschrijving model 1 Hypotheek aanvraag

Dit proces beschrijft het aanvragen en goedkeuren van een hypotheek bij de bank.

Aan het begin wordt het initiële hypotheekverzoek van de klant ingevoerd in het systeem van de bank. Daarna controleert de bank of ze over alle informatie beschikken wat nodig is om het proces van hypotheekaanvraag te starten. Wanneer dit niet het geval is, neemt de bank contact op met de klant om de ontbrekende informatie op te vragen. Deze stap wordt herhaald totdat alle informatie compleet is. Zodra alle informatie binnen is, berekent de bank het beschikbare bedrag voor de klant, het jaarinkomen en het benodigde bedrag om het huis te kopen. Deze berekeningen zijn allemaal onafhankelijk van elkaar en kunnen parallel worden uitgevoerd. Na alle controles, wordt de hypotheek geïnspecteerd zoals nu wordt beschreven. Als de hypotheek lager is dan 1.000.000, is één medewerker voldoende om een beslissing te maken over de hypotheekaanvraag. Voor hypotheken gelijk aan of groter dan 1.000.000 is er een tweede medewerker nodig om een beslissing te maken. In het laatste geval evalueren de twee medewerkers de aanvraag individueel. Dit gebeurd parallel aan elkaar. Naderhand ontmoeten ze elkaar om samen een beslissing te maken. Als de hypotheekaanvraag is goedgekeurd voor zowel een hypotheek van lager dan 1.000.000 als een hypotheek van groter dan 1.000.000, bereidt de bank een hypotheekaanbieding voor. De bank stuurt het aanbod naar de klant. Daarna evalueert de bank de antwoordformulieren die geretourneerd zijn door de klant. Als de klant de voorgestelde voorwaarden accepteert die in de aanbieding staan, wordt het geld beschikbaar gesteld via een aanbetaling. De aanvraag is hierna gesloten waarmee het proces eindigt. Als de klant de voorgestelde voorwaarden niet accepteert, neemt de bank contact op met de klant om te informeren naar de redenen hiervoor. Hierna wordt de reactie van de klant geëvalueerd door de bank. Als de bank met de reactie akkoord gaat, wordt de aanvraag bijgewerkt en opnieuw verstuurd naar de klant. Als de klant nu wel akkoord gaat, zet de bank het geld beschikbaar en eindigt het proces. Als de bank niet akkoord gaat met de reactie van de klant, wordt de aanvraag afgekeurd en wordt het proces gesloten.

B.4 Model 1 Session 1

Figure 45: *Model 1 session 1*



B.5 Model description 2 Session 1

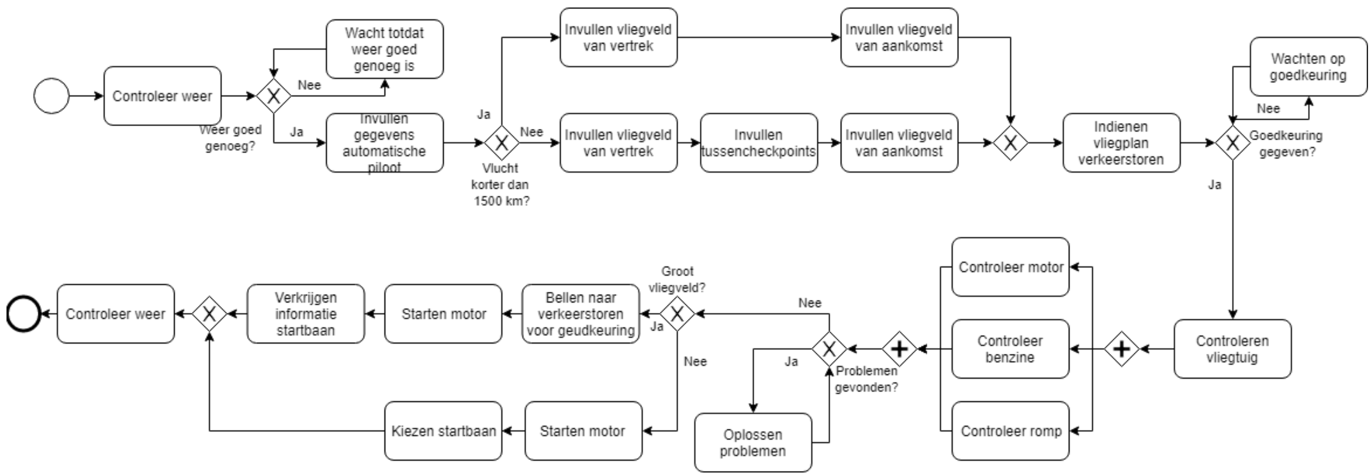
Beschrijving model 2 Opstijgen vliegtuig

Dit proces beschrijft het klaarmaken en opstijgen van een vlucht.

Eerst moet de piloot het weer controleren. Als het weer niet goed is, wacht de piloot totdat het weer goed genoeg is om te vliegen. Als het weer goed is, kan de piloot de juiste gegevens in de automatische piloot invullen. Wanneer de vlucht korter dan 1500 km is wordt achtereenvolgens het vliegveld van vertrek en het vliegveld van aankomst ingevuld. Wanneer de vlucht langer is dan 1500 km wordt achtereenvolgens het vliegveld van vertrek, tussen checkpoints en het vliegveld van aankomst ingevuld in de automatische piloot. Vervolgens wordt het vliegplan ingediend bij de verkeerstoren. Als de verkeerstoren goedkeuring heeft gegeven voor het vliegplan wordt het vliegtuig gecontroleerd. Wanneer de verkeerstoren geen goedkeuring heeft gegeven, wacht de piloot totdat er wel goedkeuring is gegeven. Bij de controle van het vliegtuig wordt de motor, benzine en romp gecontroleerd. Deze controle activiteiten kunnen onafhankelijk van elkaar worden uitgevoerd. Wanneer er problemen gevonden zijn worden deze eerst opgelost voordat het proces verder gaat. Wanneer er geen problemen gevonden zijn, belt de piloot bij grote vliegvelden naar de verkeerstoren om goedkeuring te krijgen om de motor te starten. Vervolgens wordt de motor gestart. Bij kleine vliegvelden start de piloot de motor zonder dat er goedkeuring nodig is. Bij grote vliegvelden krijgt de piloot informatie van de verkeerstoren naar welke startbaan er getaxied kan worden, vervolgens kan het vliegtuig opstijgen. Bij kleine vliegvelden kiest de piloot zelf een startbaan en stijgt ze op.

B.6 Model 2 Session 1

Figure 46: *Model 2 session 1*



C Session 2

C.1 Instruction form

Proces modelleren met think aloud

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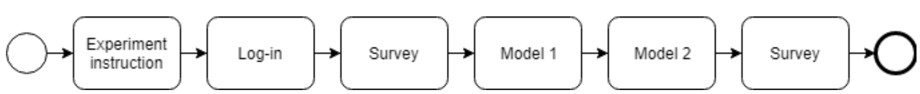
Think aloud

Think aloud wordt gebruikt om je gedachtes te analyseren wanneer je bezig bent met het maken van een model. Dit kan gebruikt worden om de verschillende strategieën voor het maken van een model te onderscheiden. Jullie gedachtes worden opgenomen en kunnen daardoor later geanalyseerd worden. Wat is precies de bedoeling van think aloud:

- Het is de bedoeling dat je al je gedachtes hardop uitspreekt wanneer je bezig bent met het maken van een model. Blijf alles wat in je gedachte opkomt uitspreken gedurende het gehele experiment.
- Je mag in het Nederlands of Engels spreken.
- Tijdens het modelleren is het niet mogelijk om vragen te stellen. Ik zal alleen het proces onderbreken om te wijzen op het blijven uitspreken van je gedachtes waar nodig.

Uitvoering experiment

Tijdens elke modelleersessie werk je aan twee modellen. De sessie zal beginnen met een korte vragenlijst, gevolgd door twee modelleertaken. De sessie zal ook weer eindigen met een korte vragenlijst.



Laat je niet uit de weg slaan door de complexiteit van de modellen. Zie het als een uitdaging om het model zo goed mogelijk te maken. Je mag alle tijd nemen voor het maken van de modellen. Vergeet niet om al je gedachtes hardop en duidelijk uit te spreken.

C.2 Model description 1 Session 2

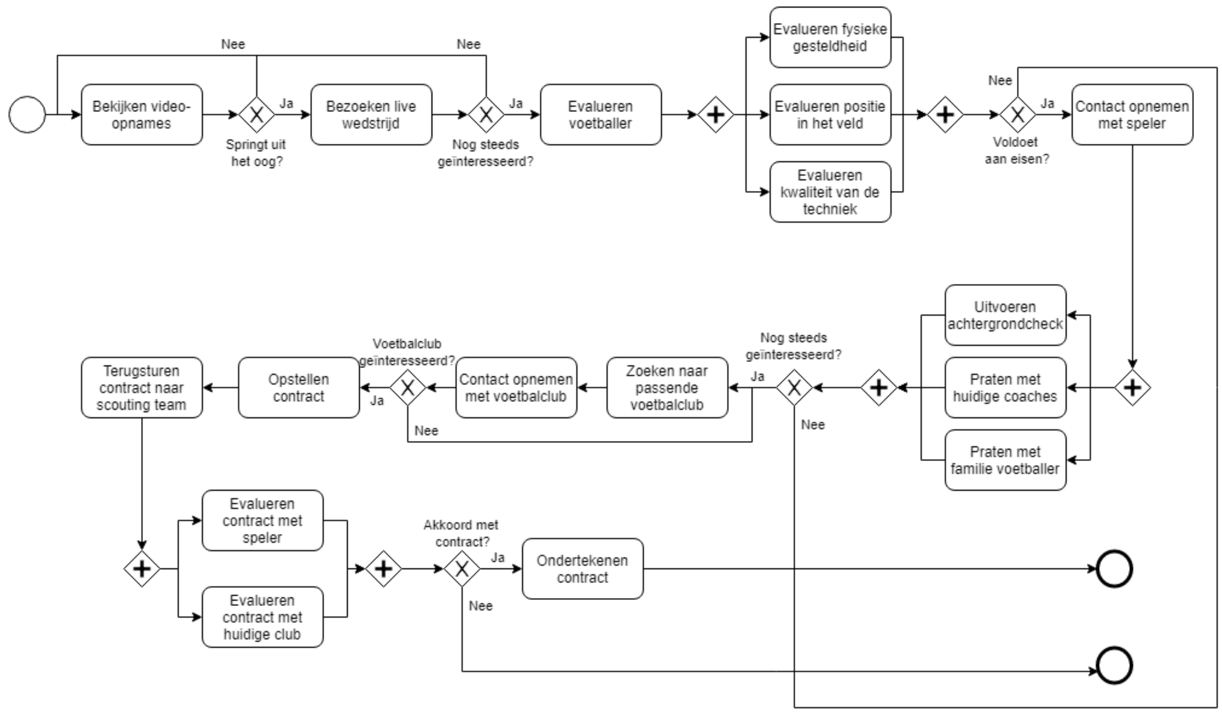
Beschrijving model 1 scoutingproces voetballer

Dit proces beschrijft het scouten van een voetballer.

Aan het begin van het proces kijkt het scouting team naar video-opnames van voetbalwedstrijden. Als een voetballer uit het oog springt, gaat het scouting team naar een live wedstrijd kijken. Anders worden er opnieuw video-opnames bekeken. Als het scouting team, na het kijken van een live wedstrijd, nog steeds geïnteresseerd is, evalueren ze de voetballer bij een vergadering waar het gehele scouting team aanwezig is. Als het team niet meer geïnteresseerd is, begint het proces van kijken naar video-opnames opnieuw. Bij het evalueren van de voetballer wordt er gekeken naar fysieke gesteldheid, positie in het veld, en de kwaliteit van de techniek. Deze activiteiten kunnen parallel aan elkaar worden uitgevoerd. Als de voetballer aan deze eigenschappen voldoet, wordt er contact opgenomen met de speler. Anders wordt het proces beëindigd. Nadat er contact opgenomen is met de speler, wordt er een achtergrond check gedaan. Tegelijkertijd praat het scouting team met de huidige coaches van de voetballer, en de familie van de voetballer. Als het scouting team nog steeds geïnteresseerd is, gaat het team op zoek naar een passende voetbalclub voor de voetballer. Anders eindigt het proces. Wanneer er een passende voetbalclub is gevonden, neemt het scouting team contact op met de voetbalclub. Wanner de voetbalclub niet geïnteresseerd is in de voetballer, gaat het scouting team op zoek naar een nieuwe voetbalclub. Wanneer de voetbalclub wel geïnteresseerd is, stelt de voetbalclub een contract op. Vervolgens wordt het contract teruggestuurd naar het scouting team. Het scouting team evalueert het contract met zowel de speler als de huidige club van de speler. Als de speler en de huidige club akkoord gaan met het contract, wordt het contract getekend en eindigt het proces. Als de speler of de huidige club niet akkoord gaat, eindigt ook het proces.

C.3 Model 1 Session 2

Figure 47: *Model 1 session 2*



C.4 Model description 2 Session 2

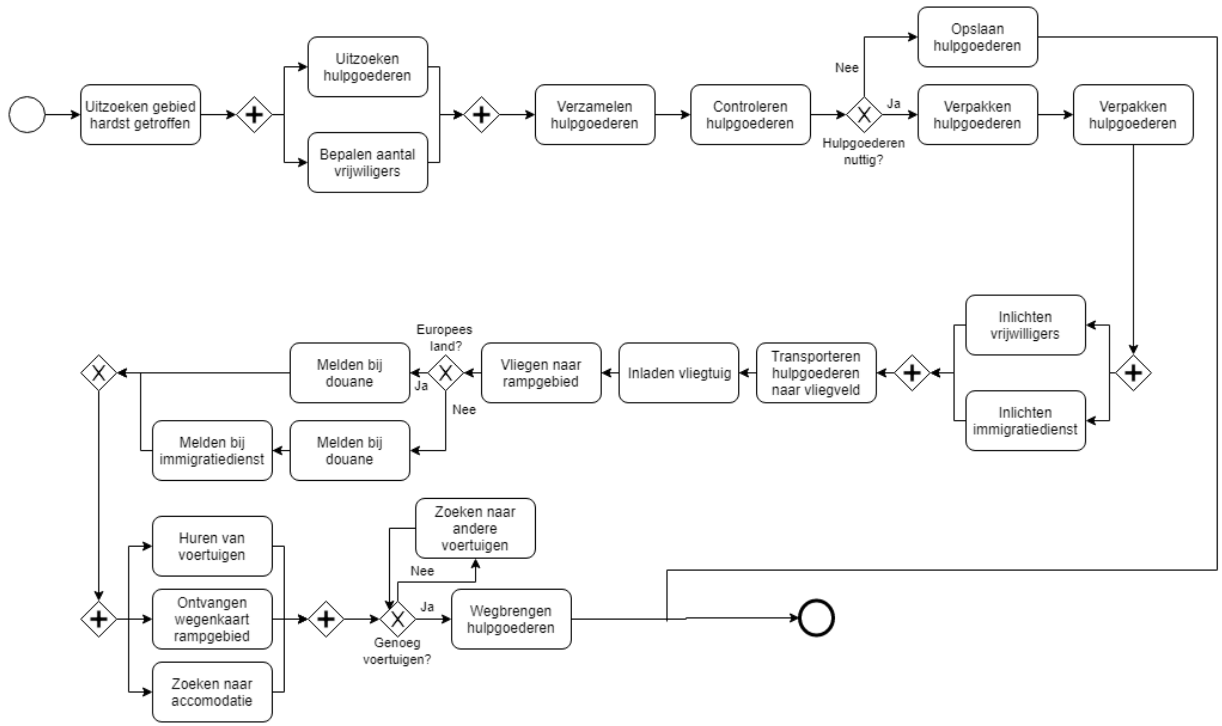
Beschrijving model 2 Hulp rampgebieden Rode kruis

Dit proces beschrijft het transportproces van hulpgoederen naar rampgebieden.

Eerst wordt er uitgezocht welk gebied het hardst getroffen is. Tegelijkertijd wordt er uitgezocht welke hulpgoederen er in dat gebied nodig zijn en hoeveel vrijwilligers mee moeten om de hulpgoederen uit te delen. Vervolgens worden alle hulpgoederen verzameld op één plek en gecontroleerd. Hulpgoederen die nuttig zijn in het rampgebied worden verpakt. Ontvangen hulpgoederen die niet nodig zijn in het rampgebied worden opgeslagen voor een latere missie waarmee het proces beëindigd wordt. Vervolgens wordt het transport voorbereid. Zowel de vrijwilligers als de immigratiedienst van het gastland moeten worden ingelicht. Dit kan parallel aan elkaar plaatsvinden. Daarna worden de verpakte hulpgoederen getransporteerd naar het vliegveld van vertrek waarna het vliegtuig ingeladen kan worden. Vervolgens vliegt het vliegtuig naar het rampgebied. Wanneer het rampgebied in een niet Europees land ligt, presenteren de vrijwilligers zichzelf eerst bij de douane en vervolgens bij het kantoor van de immigratiedienst. Wanneer het rampgebied in een Europees land ligt, hoeven de vrijwilligers alleen langs de douane. Vervolgens worden er voertuigen gehuurd om de hulpgoederen naar de juiste plek te vervoeren. Tegelijkertijd ontvangen ze een wegenkaart van het rampgebied en gaan ze op zoek naar een accommodatie. Wanneer er niet genoeg voertuigen gehuurd kunnen worden, gaan de hulptroepen op zoek naar andere voertuigen totdat er genoeg voertuigen beschikbaar zijn. Wanneer er genoeg transportvoertuigen aanwezig zijn, worden de hulpgoederen weggebracht en eindigt het proces.

C.5 Model 2 Session 2

Figure 48: *Model 2 session 2*



D Session 3

D.1 Instruction form

Proces modelleren met think aloud

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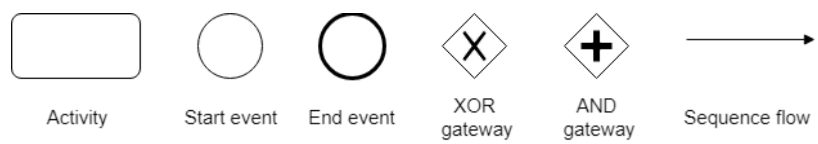


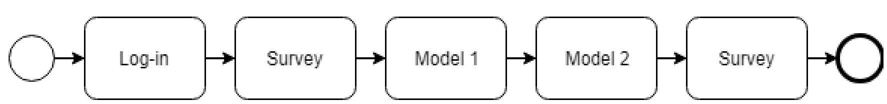
Think aloud

Think aloud wordt gebruikt om je gedachtes te analyseren wanneer je bezig bent met het maken van een model. Dit kan gebruikt worden om de verschillende strategieën voor het maken van een model te onderscheiden. Jullie gedachtes worden opgenomen en kunnen daardoor later geanalyseerd worden. Wat is precies de bedoeling van think aloud:

- Het is de bedoeling dat je al je gedachtes hardop uitspreekt wanneer je bezig bent met het maken van een model. Blijf alles wat in je gedachte opkomt uitspreken gedurende het gehele experiment.
- Je mag in het Nederlands spreken.
- Tijdens het modelleren is het niet mogelijk om vragen te stellen. Ik zal alleen het proces onderbreken om te wijzen op het blijven uitspreken van je gedachtes waar nodig.

Uitvoering experiment

Tijdens elke modelleersessie werk je aan twee modellen. De sessie zal beginnen met een korte vragenlijst, gevolgd door twee modelleertaken. De sessie zal ook weer eindigen met een korte vragenlijst.



Laat je niet uit de weg slaan door de complexiteit van de modellen. Zie het als een uitdaging om het model zo goed mogelijk te maken. Je mag alle tijd nemen voor het maken van de modellen. Vergeet niet om al je gedachtes hardop en duidelijk uit te spreken.

D.2 Model description 1 Session 3

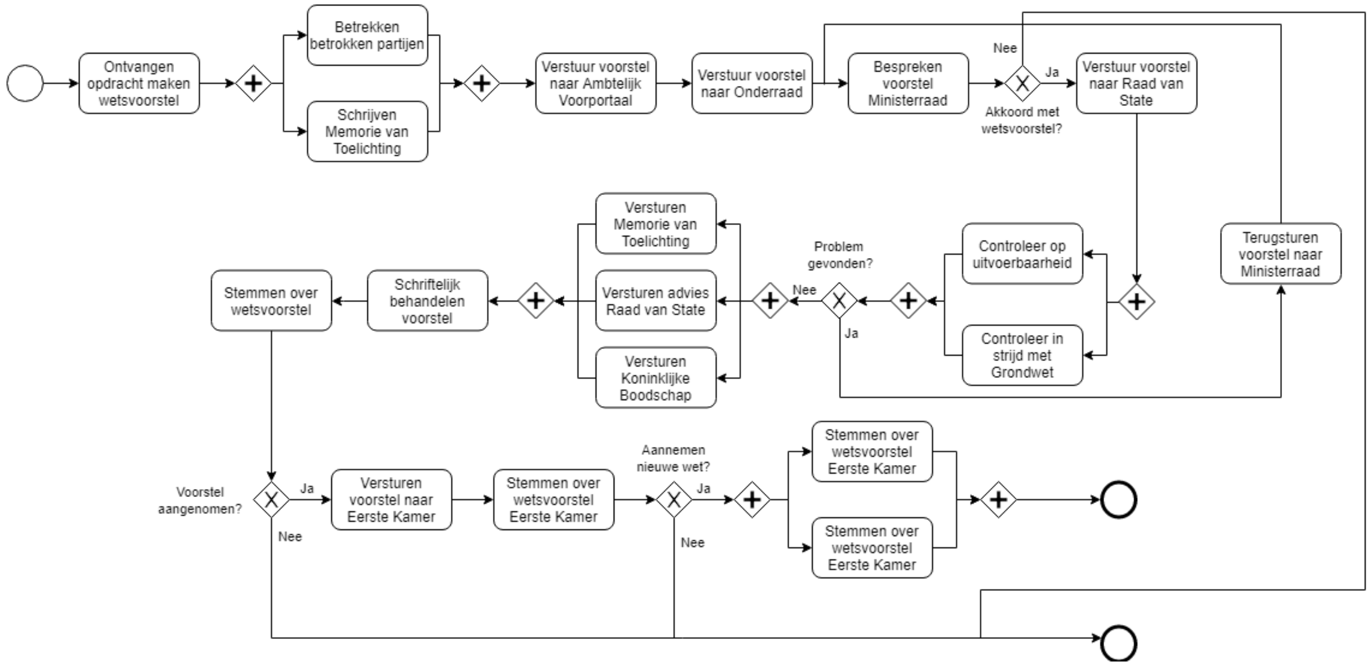
Beschrijving model 1 wetsvoorstel

Dit proces beschrijft het tot stand komen van een wet.

Aan het begin van het proces krijgen de ambtenaren de opdracht om een wetsvoorstel te maken. De ambtenaren betrekken vervolgens de partijen erbij voor het wie de wet van belang is en schrijven ze een Memorie van Toelichting. Deze stappen kunnen parallel aan elkaar worden uitgevoerd. Daarna wordt het voorstel naar het ambtelijk voorportaal gestuurd. Vervolgens wordt het voorstel naar de onderraad gestuurd. Hierna wordt het voorstel besproken bij de ministerraad waar alle ministers betrokken zijn. De ministerraad kan wel of niet akkoord gaan met het wetsvoorstel. Wanneer de ministerraad wel akkoord gaat, wordt het voorstel verstuurd naar de Raad van State. Wanneer de ministerraad niet akkoord gaat met het voorstel, wordt het proces beëindigd. De Raad van State controleert het voorstel op uitvoerbaarheid en tegelijkertijd of het in strijd is met de grondwet. Wanneer er geen problemen gevonden zijn door de Raad van State wordt de Memorie van Toelichting, het advies van de Raad van State en de Koninklijke Boodschap verstuurt naar de Tweede Kamer. Deze stappen kunnen ook weer parallel aan elkaar worden uitgevoerd. Wanneer er wel problemen gevonden zijn door de Raad van State wordt het voorstel teruggestuurd naar de ministerraad waar het wetsvoorstel opnieuw besproken wordt. In de Tweede Kamer wordt het voorstel eerst schriftelijk behandeld. Vervolgens stemt de Tweede kamer over het wetsvoorstel. Als het wetsvoorstel is aangenomen wordt het wetsvoorstel verstuurd naar de Eerste Kamer. Wanneer het wetsvoorstel niet is aangenomen eindigt het proces. In de Eerste Kamer vindt er vervolgens een stemming plaats over het wetsvoorstel. De eerste kamer verwerpt of neemt de nieuwe wet aan. Wanneer het wetsvoorstel verwerpt wordt, eindigt het proces. Wanneer de Eerste Kamer het wetsvoorstel aanneemt, ondertekenen de Koning en de verantwoordelijke minister tegelijkertijd de wettekst en eindigt het proces.

D.3 Model 1 Session 3

Figure 49: *Model 1 session 3*



D.4 Model description 2 Session 3

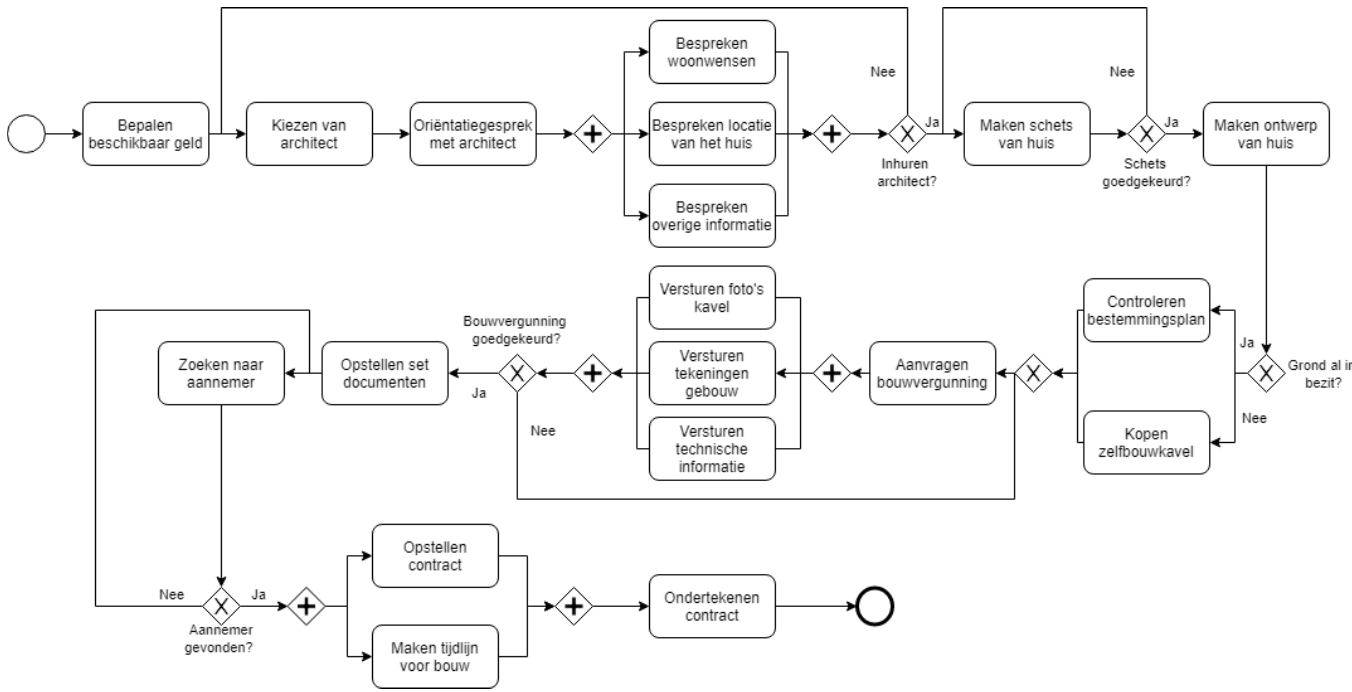
Beschrijving model 2 bouwen huis

Dit proces beschrijft het bouwen van een huis.

Aan het begin van het proces moet er bepaalt worden hoeveel geld er beschikbaar is om het huis te bouwen. Vervolgens wordt er een architect gekozen en vindt er een oriëntatiegesprek plaats bij die architect. De woonwensen, locatie van het huis en overige informatie over het bouwen van een huis worden besproken. Dit kan parallel aan elkaar plaatsvinden. Na het gesprek wordt er bepaalt of de architect wel of niet ingehuurd wordt voor het project. Wanneer dit niet het geval is, wordt er opnieuw een architect gekozen. Wanneer dit wel het geval is, maakt de architect een schets van het huis. Wanneer de schets is goedgekeurd, maakt de architect een ontwerp. Wanneer de schets niet wordt goedgekeurd, wordt er een nieuwe schets gemaakt door de architect. Vervolgens moet er een vergunning komen voor het bouwen van het huis. Het is mogelijk dat de grond al in bezit is van de eigenaar of dat er een kavel gekocht moet worden. Wanneer de grond al in het bezit is van de eigenaar wordt het bestemmingsplan gecontroleerd en vervolgens kan de bouwvergunning worden aangevraagd. Als de kavel nog gekocht moet worden, wordt er een zelfbouwkavel gekocht en wordt vervolgens de bouwvergunning aangevraagd. Bij het aanvragen van de bouwvergunning moeten foto's van de kavel, tekeningen van het gebouw, en technische informatie worden meegestuurd. Wanneer de bouwvergunning niet wordt goedgekeurd, begint de aanvraag van een bouwvergunning opnieuw. Wanneer de bouwvergunning wel goedgekeurd wordt, kan de voorbereiding van de bouw beginnen. Eerst stelt de architect een complete set documenten op voor de aannemer. Vervolgens wordt er gezocht naar een aannemer. Dit proces gaat door totdat er een geschikte aannemer is gevonden. Is er een aannemer gekozen? Dan stelt de aannemer een contract op. Tegelijkertijd wordt er een tijdlijn gemaakt voor de bouw. Vervolgens wordt het contract getekend en eindigt het proces.

D.5 Model 2 Session 3

Figure 50: *Model 2 session 3*



E Session 4

E.1 Model description 1 Session 4

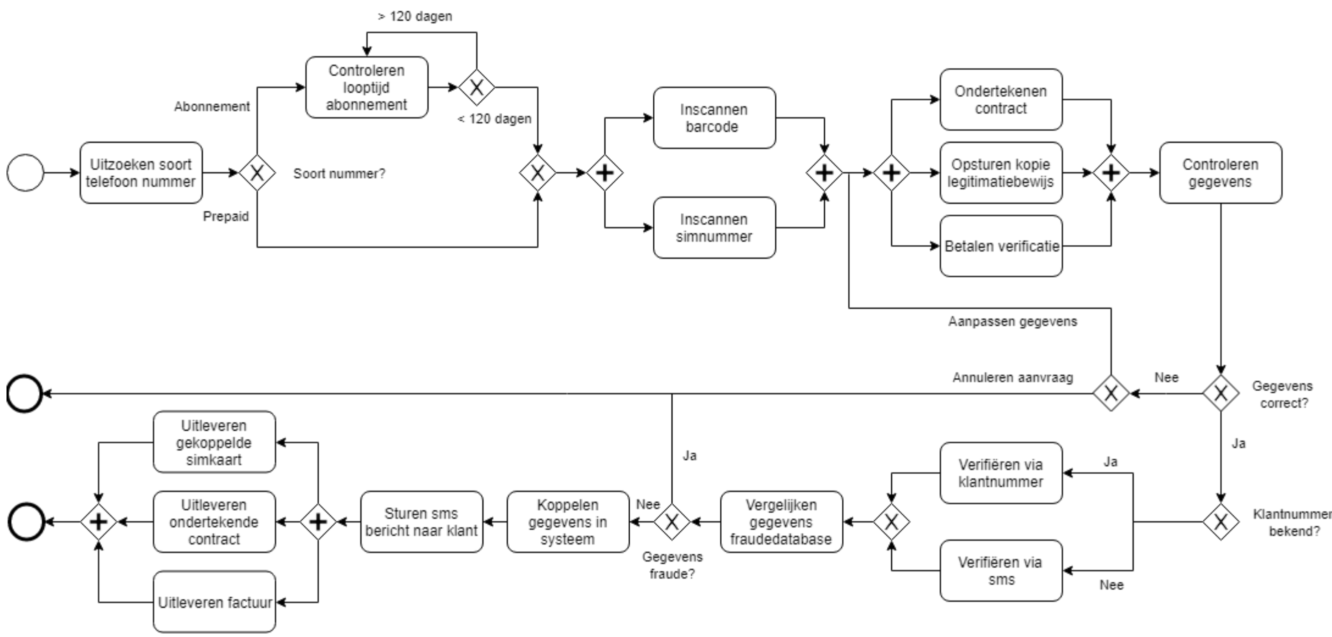
Beschrijving model 1 Overstappen telefoonabonnement

Dit proces beschrijft het overstappen bij providers van een telefoonabonnement met nummerbehoud.

Eerst wordt er gekeken of het te behouden nummer een prepaidnummer is of een nummer wat al gekoppeld is aan een abonnement. In het eerste geval kan de aanvraag direct behandeld worden. Anders moet er eerst gekeken worden naar de looptijd van het abonnement. Bij een overstap naar een andere provider geldt de volgende regel: Wanneer de verloopdatum van het abonnement minder dan 120 dagen vanaf nu is, kan de aanvraag direct verwerkt worden, anders wordt de aanvraag uitgesteld totdat verloopdatum binnen een periode van 120 dagen valt. Voor de aanvraag moet er vervolgens een nieuwe simkaart gekoppeld worden aan de order. Dit wordt gedaan door de barcode en het simnummer in te scannen. Daarna moet de klant het contract ondertekenen en een kopie van zijn of haar legitimatiebewijs opsturen. Daarnaast moet er ook nog een verificatiebetaling plaatsvinden. Dit alles wordt gecontroleerd, en er wordt gekeken of alle gegevens overeenkomen op de verschillende documenten. Mocht dit niet kloppen, moeten de gegevens door de klant aangepast worden door middel van het opsturen van een nieuwe versie van één of meerdere documenten, of wordt de aanvraag geannuleerd. Als alles klopt, kan de verwerking verder gaan. Als de klant zijn of haar klantnummer weet van de huidige provider, kan hij deze invullen. Dit wordt gebruikt als verificatiegegeven. De klant kan zich ook verifiëren via een sms-bericht, die vanuit de provider verstuurd wordt. De gegevens worden ook nog vergeleken met een fraudedatabase. De provider kan besluiten om op basis van deze gegevens de klant af te wijzen en de aanvraag te annuleren. Als dit niet het geval is, worden de gegevens in het systeem van de provider gekoppeld. De provider stuurt een sms bericht naar de klant om aan te geven dat het allemaal gelukt is. De gekoppelde simkaart wordt uitgeleverd, samen met het ondertekende contract en de factuur van de order waarmee het proces eindigt.

E.2 Model 1 Session 4

Figure 51: *Model 1 session 4*



E.3 Model description 2 Session 4

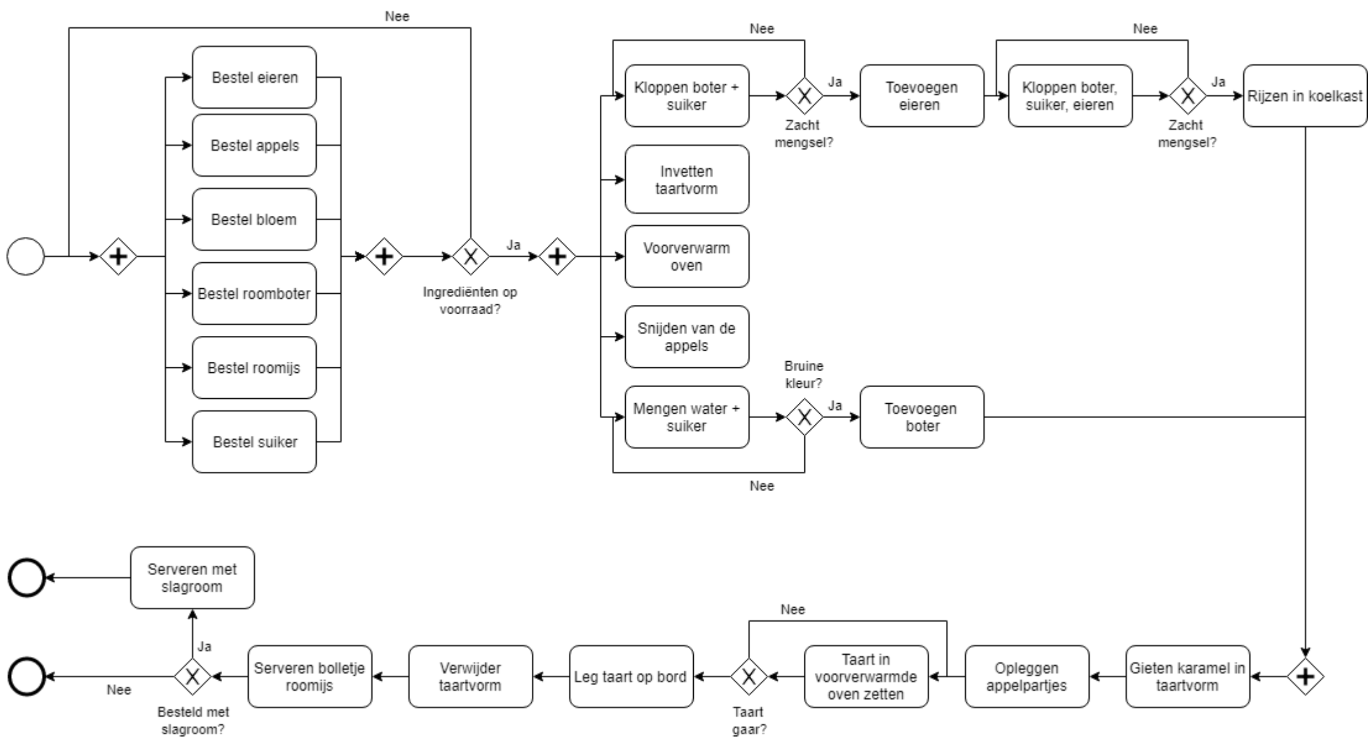
Beschrijving model 2 Bereiden Tarte tatin

Dit proces beschrijft de bereiding van een tarte tatin in een restaurant.

In een restaurant kan je verschillende desserts bestellen. Een mogelijke optie is een tarte tatin. In dit dessert gaan eieren, appels, bloem, roomboter, roomijs, en suiker. De verantwoordelijke voor de inkopen van het restaurant moet ervoor zorgen dat deze producten voldoende op voorraad zijn. Is dit niet het geval, dan moeten ingrediënten bijbesteld worden. Als alle ingrediënten op voorraad zijn, kan het maken van de tarte tatin beginnen. Er zijn een paar acties die het keukenpersoneel uitvoeren: het deeg moet gemaakt worden, de karamel moet gemaakt worden, de taartvorm moet ingevet worden, de oven moet voorverwarmd worden, en de appels moeten in kwartjes gesneden worden. De meeste dingen spreken voor zich, maar het maken van het deeg en de karamel vereist wat meer uitleg. De chef is verantwoordelijk voor de laatste twee zaken. De andere keukenmedewerkers verzorgen de rest. Voor het deeg, moet de boter met de suiker zacht geklopt worden. Het kloppen gaat door totdat het een zacht mengsel geworden is. Als dit een zacht mengsel is geworden, voegt de chef de eieren toe en blijft doorkloppen. Als dit een strak geheel is geworden, zet de chef het mengsel in de koelkast en laat dit rijzen. De karamel wordt ook door de chef bereid. Hij mengt water en suiker, en laat dit koken. De chef roert dit constant, totdat het de bruine kleur van karamel krijgt. Tenslotte wordt er boter aan het suikermengsel toegevoegd. Vervolgens kan het keukenpersoneel verder gaan met de bereiding van de taart. De karamel kan in een taartvormpje gegoten worden, waarop de appelpartjes worden gelegd. Daarna wordt het deeg verspreid over het vormpje, op een manier dat de appelpartjes afgedekt worden. De taartvorm gaat vervolgens de voorverwarmde oven in. Als de taart gaar is, wordt deze uit de oven gehaald. De taart wordt op een bord gelegd, en de vorm wordt verwijderd. Naast de taart komt een bolletje roomijs te liggen. Als de klant het gerecht inclusief slagroom heeft besteld, wordt er ook nog een toef slagroom op de tarte tatin gespoten. Het gerecht is nu klaar en wordt door de serveerder naar de klant gebracht.

E.4 Model 2 Session 4

Figure 52: *Model 2 session 4*



F Modeling results per participant

This appendix shows the modeling results per participant in more detail. The used figures are explained below with the figures for subject 1 as an example.

Figure 53 shows the modeling patterns for subject 1 for all modeling sessions. There are 188 phases in total and 180 transitions. The boxes show the total number of phases. For example, there are 75 problem understanding phases which is 39,9% of the total number of 188 phases. The transitions between the different phases are shown with the arrows. There are 68 transitions from the problem understanding phase to the modeling/reconciliation phase which is 90,7% of all transitions starting from the problem understanding phase. In figure 23, there is no arrow from the validation phase to the problem understanding phase. This means that there are no transitions from the validation phase to the problem understanding phase detected. The percentage of the transitions determines the thickness of the arrow. For percentages up to 20 percent, line thickness one is used. For 20% - 70% line thickness two is used. For percentages higher than 70 percent, line thickness three is used.

Figure 54 to figure 57 shows the modeling behavior, the sequence of phases, for each created model. The same colours are used as described above. For example, the modeler starts in session 1 model 1 with a problem understanding phase followed by a method finding phase. The modeling process ends with a modeling/reconciliation phase. The total modeling duration is shown in the middle of the semicircle.

Figure 58 shows the total number of phases for all modeling sessions for subject 1 in combination with the number of phases of each modeling phase. Figure 59 shows the modeling time for all modeling sessions for subject 1.

Table 44 shows the answers to the surveys for each modeling session. The first and the second question are only asked in the first session. The rest of the answers are given on a 5 point Likert scale. The questions above the blank line, about the confidence rate of process modeling, are asked before the modeling task. The questions below the blank line, about the perceived difficulty, are asked after the modeling task.

F.1 Subject 1

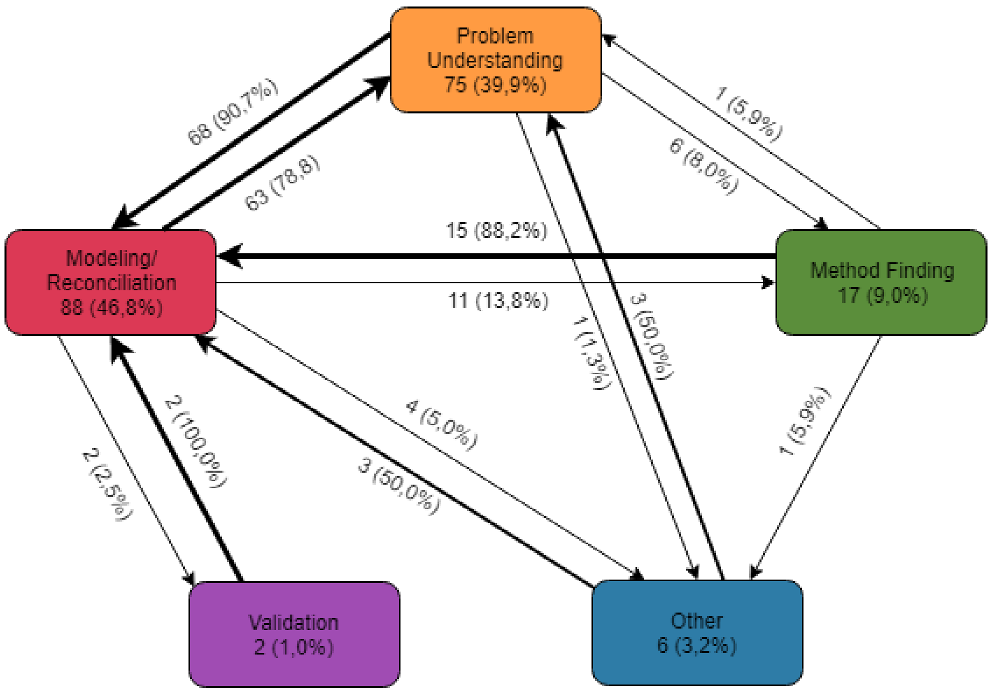
The results of subject 1 are shown below. As can be seen in figure 54 to figure 57, the modeler starts with reading the whole textual description first before moving to another phase. Except for the first problem understanding phase, there are relatively short problem understanding phases in the rest of the process of process modeling. In the first two sessions, there are some method finding phases. After session 2 (except for session 3, model 2) there are no method finding phases coded anymore. 16 of the 17 method finding phases were coded in the first two modeling sessions. This seems that it was no longer necessary to think aloud the possible modeling options. In the last two sessions, the modeler verbalized only problem understanding and modeling/reconciliation utterances. It stands out that only 1% of the phases is coded as the validation phase.

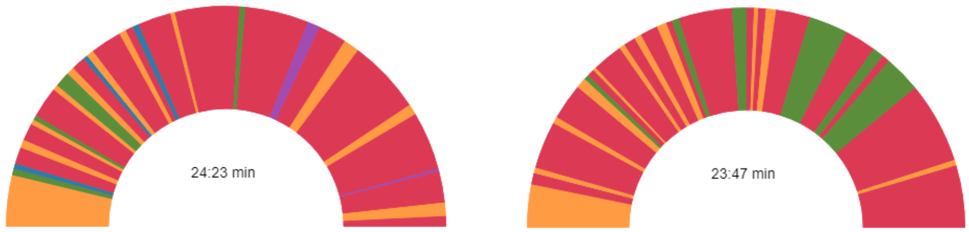
Figure 58 shows the number of phases in modeling. The number of phases is lower for the second model in session 1, 2, and 4 compared to the first model. After session 2 model 1 there is a strong decline for the number of modeling phases from 34 modeling phases in s1M1 to 20 modeling phases in S2M2. These differences are mainly due to the decline of the number of method finding, validation, and other phases. The decline of the number of phases is accompanied by a decrease of the modeling duration (figure 59). In session 1 model 2 the modeler spent 4:02 minutes in the method finding phase while 00:00 minutes were spent in the method finding phase in session 3 model 1.

Figure 53 shows that almost all transitions are between the problem understanding and the modeling/reconciliation phase (68 and 63 transitions). Almost all transitions from the method finding phase go to the modeling/reconciliation phase (88,2%). In the method finding phase, the modeler tries to find a method to translate the textual description to BPMN elements. In the modeling/reconciliation phase, the subject model the method considered in the method finding phase.

The subject experienced some modeling problems because it was not possible for the subject to model two gates in a row. There always had to be an activity in between. This sometimes caused some modeling doubts. The modeler modeled the process models step by step including activities, gateways, and sequence flows with the corresponding conditions.

Figure 53: *Modeling patterns Subject 1*

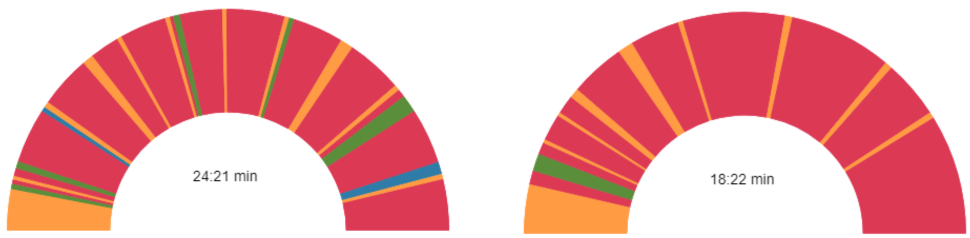




(a) Model 1

(b) Model 2

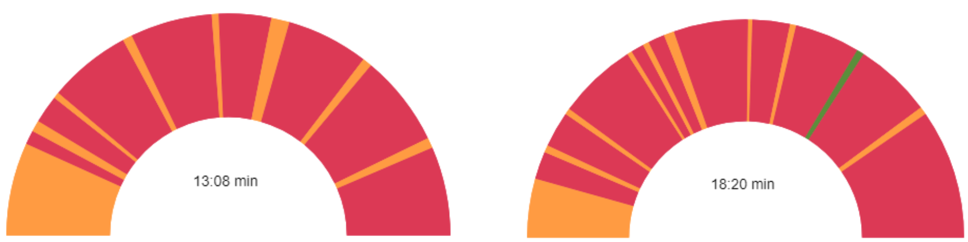
Figure 54: Subject 1, Session 1



(a) Model 1

(b) Model 2

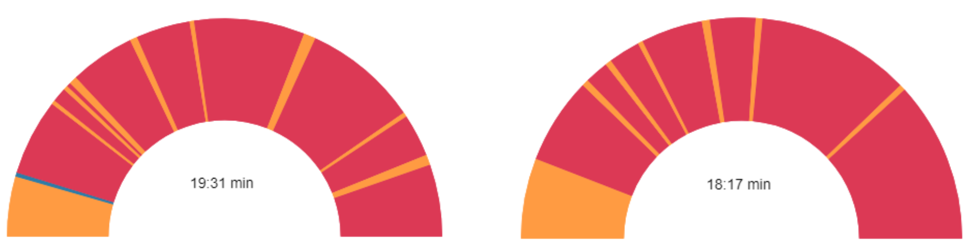
Figure 55: Subject 1, Session 2



(a) Model 1

(b) Model 2

Figure 56: Subject 1, Session 3



(a) Model 1

(b) Model 2

Figure 57: Subject 1, Session 4

Figure 58: *Frequency phases Subject 1*

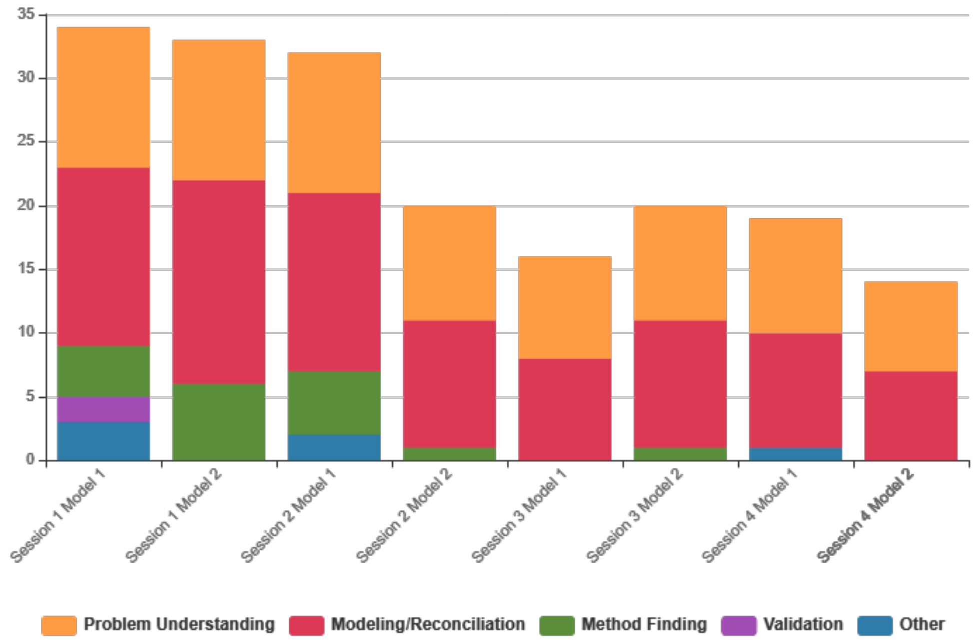


Figure 59: *Time phases Subject 1*

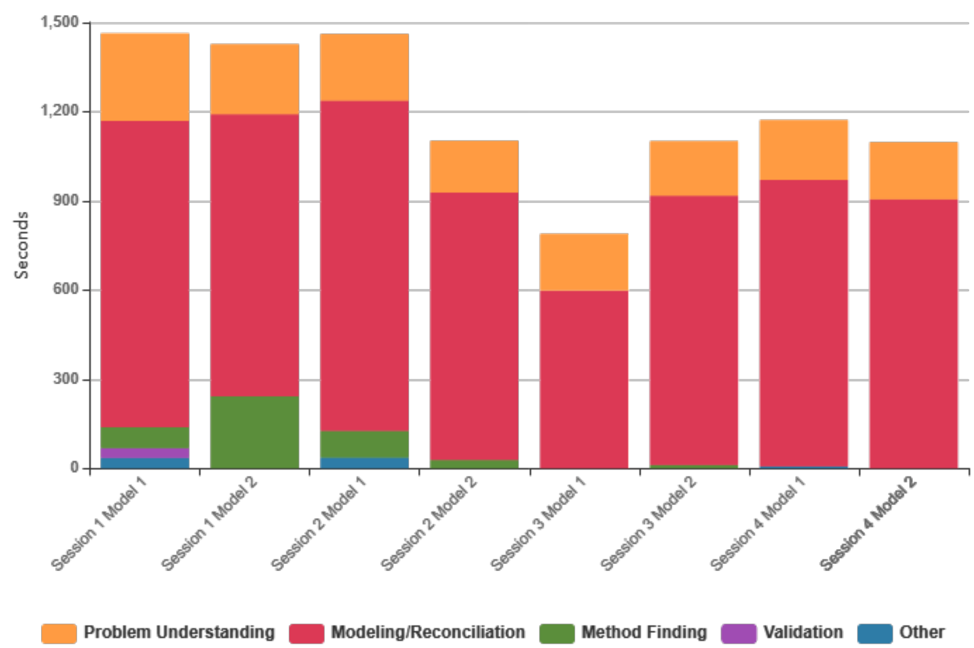


Table 44: Survey answers Subject 1

Vraag	**Session 1**	**Session 2**	**Session 3**	**Session 4**
Welke studie doe je?	Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	1e			
Ik ben goed bekend met procesmodellen.	3	4	3	4
Ik kan procesmodellen makkelijk lezen.	3	3	3	4
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	2	2	3	3
Ik vind mezelf een expert in het maken van procesmodellen.	1	2	2	3
Ik ben goed bekend met BPMN modellen.	3	3	3	5
Ik kan BPMN modellen makkelijk lezen.	4	3	3	5
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	2	2	3	4
Ik vind mezelf een expert in het maken van BPMN modellen.	3	2	2	3
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	1	2	3	2
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	3	3	3	3
Ik vond de beschrijving van proces 1 duidelijk.	3	3	4	2
Ik vond de beschrijving van proces 2 duidelijk.	4	4	4	5
Ik vond proces 1 moeilijk te begrijpen.	3	3	1	5
Ik vond proces 2 moeilijk te begrijpen.	2	2	1	2
Ik vond het maken van BPMN model 1 moeilijk.	4	3	2	3
Ik vond het maken van BPMN model 2 moeilijk.	3	3	2	2

F.2 Subject 2

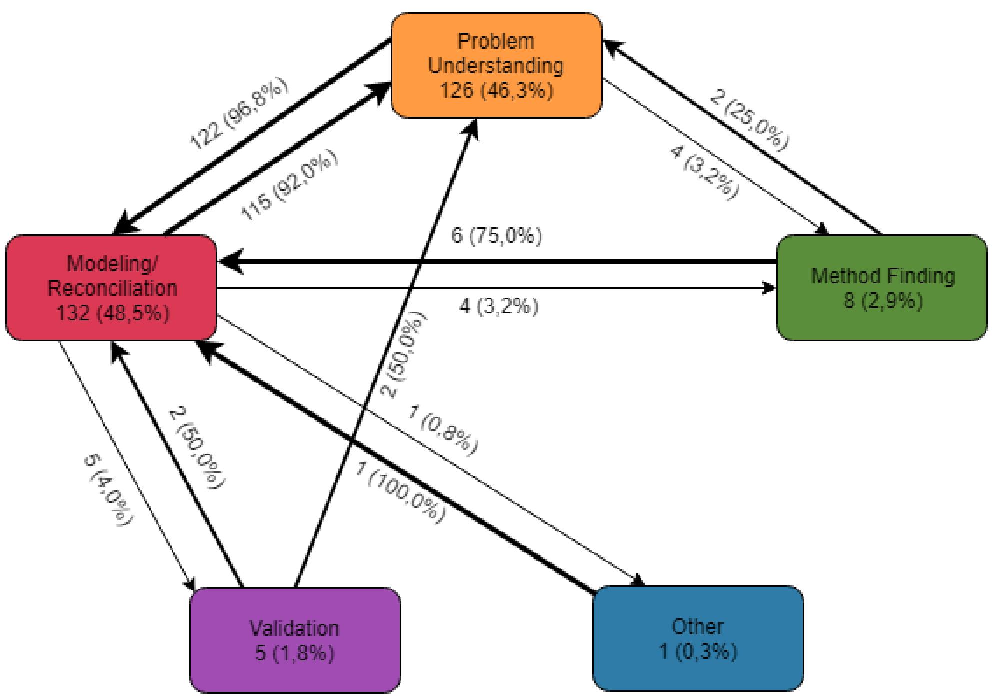
In session 1 model 1 the modeler reads the whole textual description before the modeler continuous with modeling. There are many problem understanding phases in the first model of session 1 of a long duration. The strategy changed after session 1 model 1. For the rest of the models, the modeler reads a small part of the textual description and starts modeling immediately. Less time is needed in the problem understanding phase. It is remarkable that only in session 3 model 1 multiple validation phases are coded. In the rest of the models, there are no validation phases at all. The verbal utterances show that the subject had difficulties with some parts of the textual description and wanted to check the created model. However, the survey answers show that the subject experienced the second model of session 2 as more difficult while no validation utterances are coded in the second model. The subject modeled in the first two sessions step by step. In the last two sessions, the subject started with modeling the activities and gateways and modeled the sequence flows at the end of the process which explains the long modeling/reconciliation phases at the end.

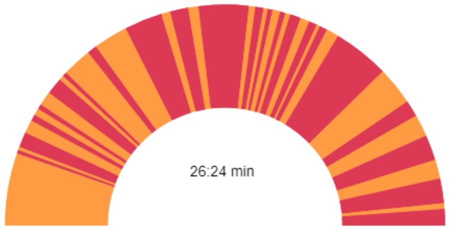
Figure 65 shows the number of phases with an outlier in session 2 model 1. As said before, the subject had some difficulties with modeling this BPMN model. The number of phases is lower for the second model of each session compared to the first one. In figure 36 the total duration of each phase is shown. It stands out that in session 1 model 1 a lot of time is spent in the problem understanding phase (12:51 min) compared to the other models.

Figure 60 shows the modeling patterns. Most transitions are between the problem understanding phase and the modeling/reconciliation phase (122 and 115). 96,8% of the transitions started in the problem understanding phase go to the modeling/reconciliation phase. The validation phase and the other phase are rarely coded.

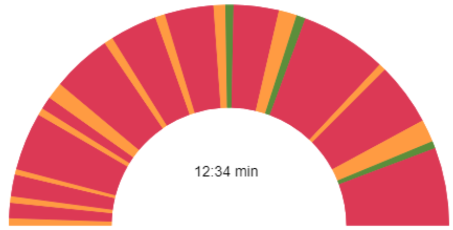
Overall, the verbal utterances were very chaotic at the beginning of this experiment. The subject had to read parts of the textual description multiple times in the problem understanding phase before it was possible to translate it into BPMN elements. During the sessions, the strategy changed and the verbal utterances became less chaotic. The modeler modeled many activities. Instead of using conditions in combination with sequence flows, the conditions are all modeled as activities.

Figure 60: *Modeling patterns Subject 2*



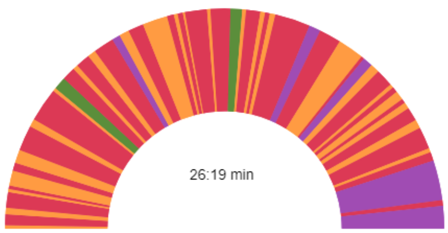


(a) Model 1

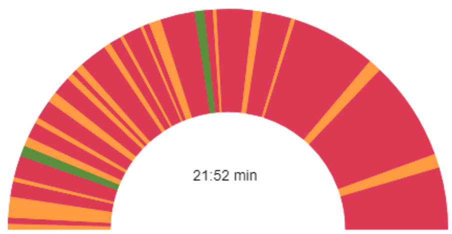


(b) Model 2

Figure 61: Subject 2, Session 1

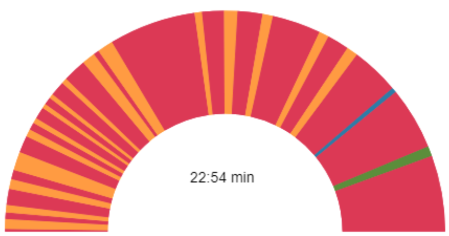


(a) Model 1

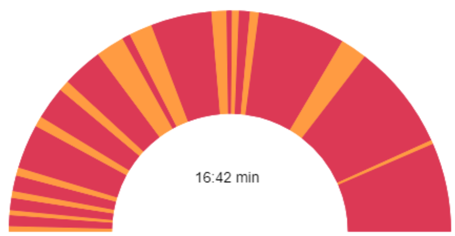


(b) Model 2

Figure 62: Subject 2, Session 2

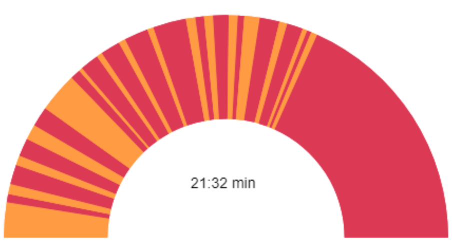


(a) Model 1

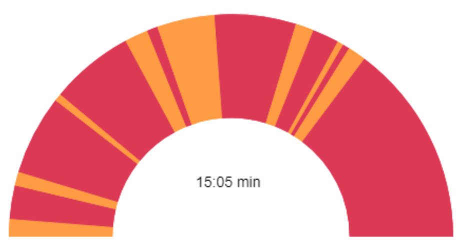


(b) Model 2

Figure 63: Subject 2, Session 3



(a) Model 1



(b) Model 2

Figure 64: Subject 2, Session 4

Figure 65: *Frequency phases Subject 2*

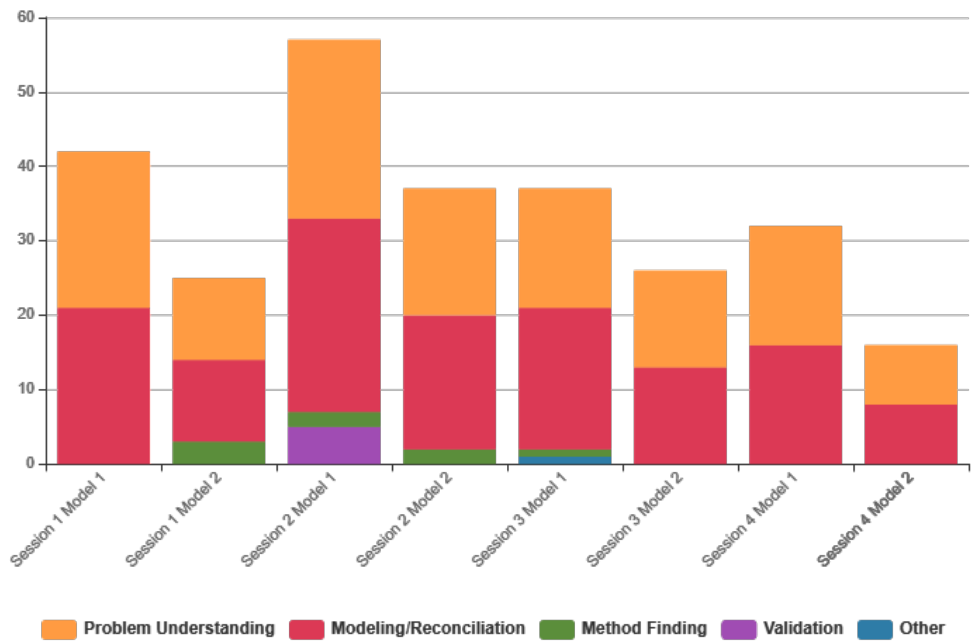


Figure 66: *Time phases Subject 2*

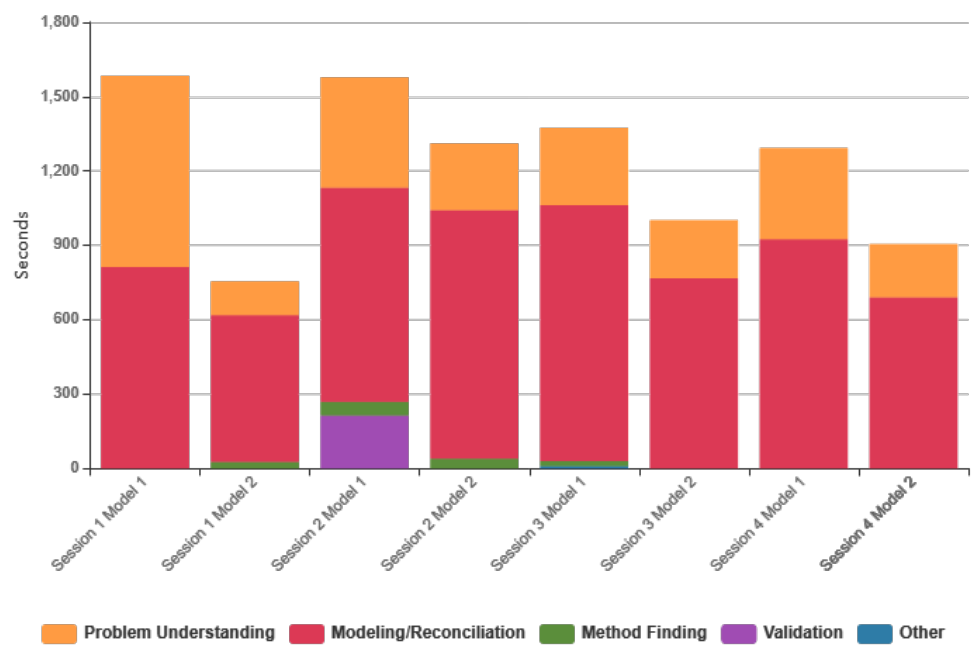


Table 45: Survey answers Subject 2

Vraag	Session 1	Session 2	Session 3	Session 4
Welke studie doe je?	Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	1e			
Ik ben goed bekend met procesmodellen.	2	2	3	4
Ik kan procesmodellen makkelijk lezen.	2	2	3	3
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	2	2	3	4
Ik vind mezelf een expert in het maken van procesmodellen.	2	2	2	4
Ik ben goed bekend met BPMN modellen.	2	3	3	4
Ik kan BPMN modellen makkelijk lezen.	2	2	3	4
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	2	2	3	4
Ik vind mezelf een expert in het maken van BPMN modellen.	2	2	2	3
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	1	1	1	3
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	1	1	1	3
Ik vond de beschrijving van proces 1 duidelijk.	3	4	2	3
Ik vond de beschrijving van proces 2 duidelijk.	4	2	1	2
Ik vond proces 1 moeilijk te begrijpen.	1	2	1	4
Ik vond proces 2 moeilijk te begrijpen.	3	3	1	4
Ik vond het maken van BPMN model 1 moeilijk.	5	2	2	4
Ik vond het maken van BPMN model 2 moeilijk.	3	4	1	3

F.3 Subject 3

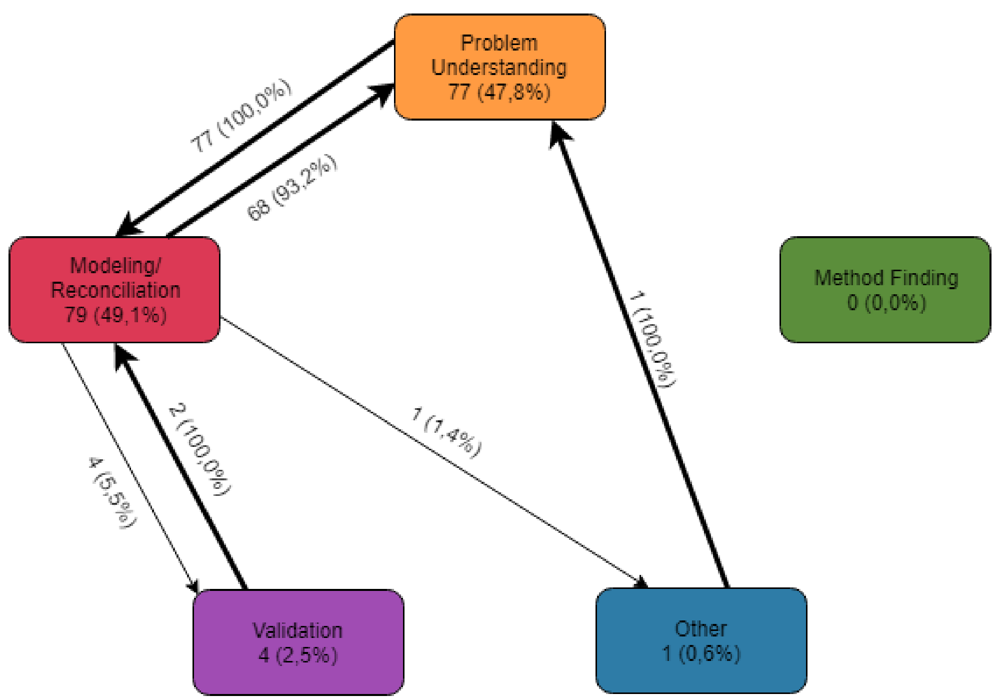
The figures for subject 3 are shown below. In the first two sessions, most of the verbal utterances are coded as the problem understanding and modeling/reconciliation phase. There are a few short validation phases at the end of the modeling process in the first four models. The subject checked the created models very quickly before adding some changes or ending the modeling process. In session 3 and session 4, there are no validation phases coded anymore. Apparently, it was no longer necessary to check the created models. In session 1 model 1 the subject reads the whole textual description first. In the rest of the models, the subject reads the first sentence in the textual description and starts modeling right afterward.

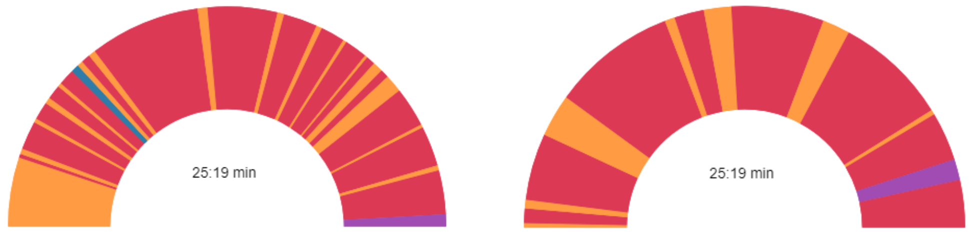
Figure 72 shows that session 1 model 1 contains the highest number of phases (34), compared to 16 phases in model 2 of the first session. This is the same for the modeling duration in session 1 model 1 (25:19 min), compared to 15:44 min in model 2 of the first session. The average number of problem understanding phases (9,6) is almost equal to the average number of modeling/reconciliation phases (9,8) per model while much more time is spent in the modeling/reconciliation phase compared to the problem understanding phase (figure 73).

The results described above can also be seen in the modeling patterns figure. Almost all modeling interactions go from the problem understand phase to the modeling/reconciliation phase and from the modeling/reconciliation phase to the problem understanding phase. There are no transitions coded between the method finding and other phase, problem understanding and method finding, modeling/reconciliation and method finding, and there are no transitions between the validation and other phase.

The subject modeled the process models step by step. The subject was able to read a part of the textual description once before translating it to BPMN elements. There was no need to think about possible modeling options. It seems that the subject is very confident about his/her modeling skills. The survey answers confirm this. The subject has no troubles with understanding the textual descriptions as well as creating the process models (table 46).

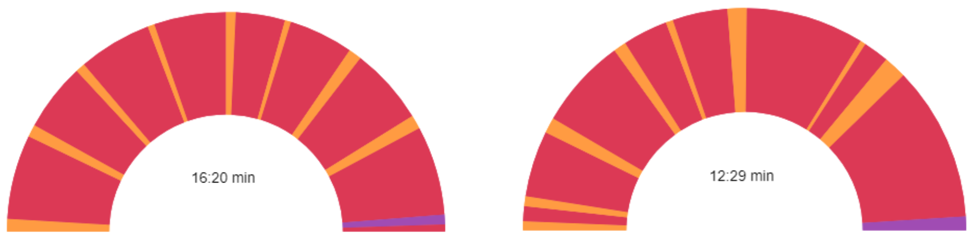
Figure 67: *Modeling patterns Subject 3*





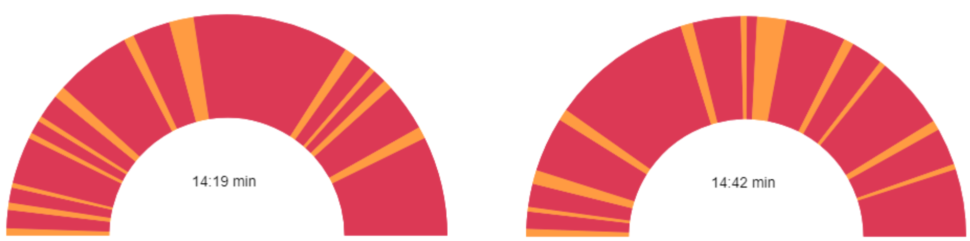
(a) Model 1 (b) Model 2

Figure 68: Subject 3, Session 1



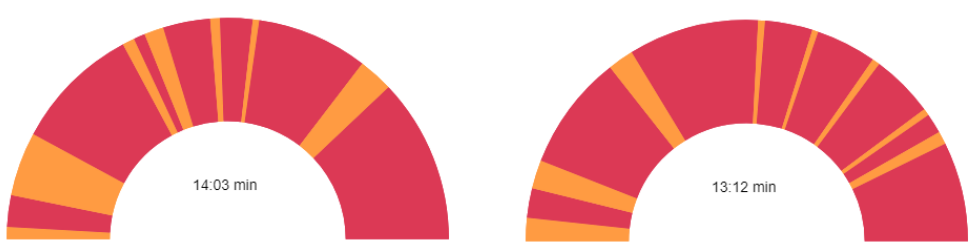
(a) Model 1 (b) Model 2

Figure 69: Subject 3, Session 2



(a) Model 1 (b) Model 2

Figure 70: Subject 3, Session 3



(a) Model 1 (b) Model 2

Figure 71: Subject 3, Session 4

Figure 72: *Frequency phases Subject 3*

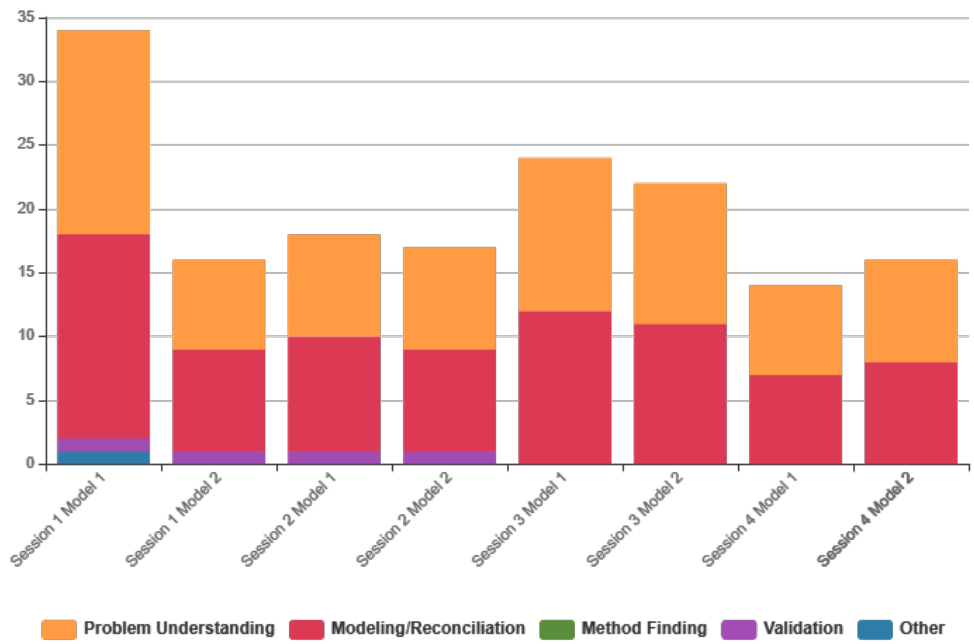


Figure 73: *Time phases Subject 3*

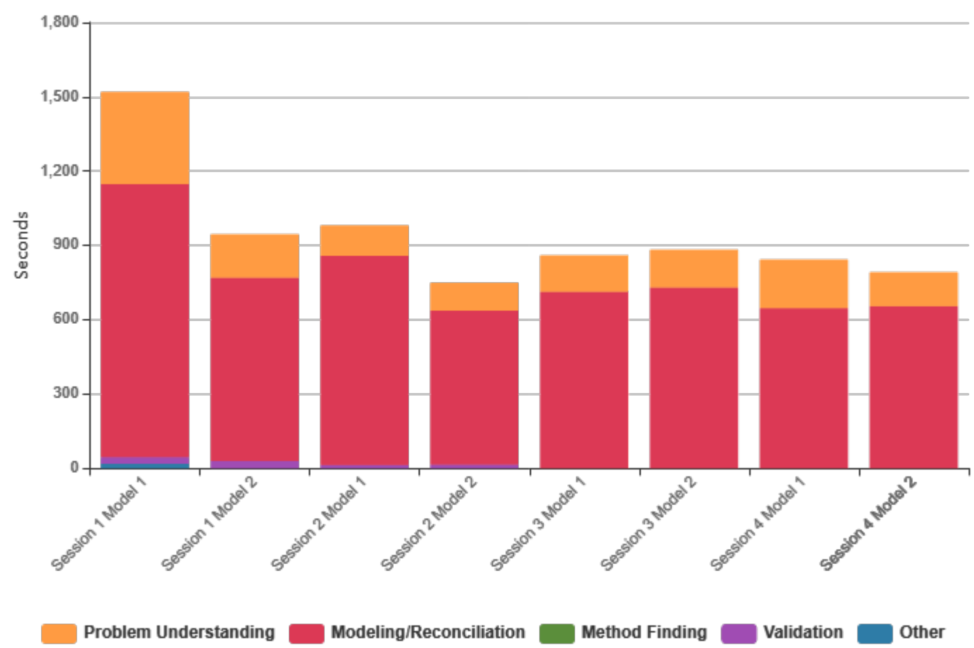


Table 46: Survey answers Subject 3

Vraag	**Session 1**	**Session 2**	**Session 3**	**Session 4**
Welke studie doe je?	Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	1e			
Ik ben goed bekend met procesmodellen.	3	4	4	5
Ik kan procesmodellen makkelijk lezen.	3	4	5	5
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	3	3	4	4
Ik vind mezelf een expert in het maken van procesmodellen.	1	2	3	3
Ik ben goed bekend met BPMN modellen.	4	4	4	5
Ik kan BPMN modellen makkelijk lezen.	5	4	5	5
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	3	4	4	4
Ik vind mezelf een expert in het maken van BPMN modellen.	2	2	3	3
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	1	1	1	4
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	1	1	3	2
Ik vond de beschrijving van proces 1 duidelijk.	4	5	5	3
Ik vond de beschrijving van proces 2 duidelijk.	5	5	5	4
Ik vond proces 1 moeilijk te begrijpen.	2	1	1	2
Ik vond proces 2 moeilijk te begrijpen.	1	2	1	2
Ik vond het maken van BPMN model 1 moeilijk.	3	1	2	2
Ik vond het maken van BPMN model 2 moeilijk.	2	1	2	2

F.4 Subject 4

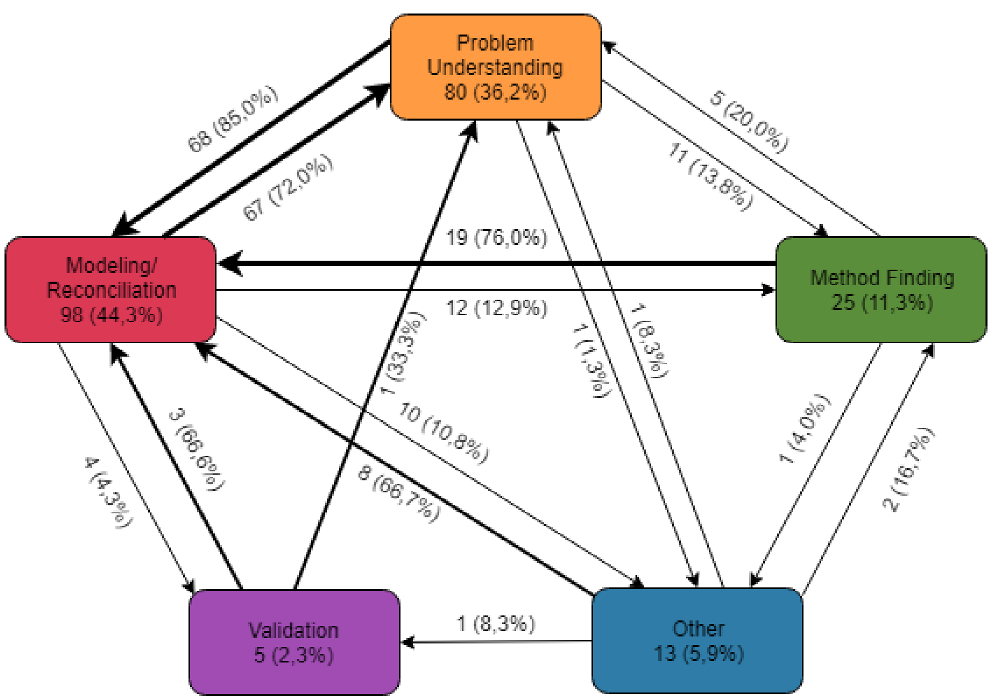
The modeler starts immediately with adding activities to the modeling canvas without reading the textual description of the process first. The modeler starts with modeling all the activities, followed by modeling the sequence flows and adding conditions. This explains the relatively long modeling/reconciliation phases at the end of the modeling process. In the first three models, there are multiple method finding phases. In the last two sessions, there are almost no method finding phases coded anymore. The modeler used almost no separate validation phases but checked the created models while modeling the sequence flows at the end of the process. The problem understanding phases have a short duration in combination with much longer modeling/reconciliation phases.

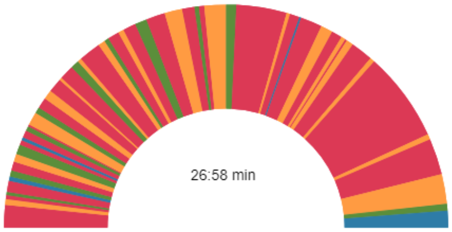
Figure 79 shows the total number of phases for each model. The second model of each session always contains a fewer number of phases compared to the first model of each session. Overall, the number of phases is decreasing during the sessions. When looking at the total duration of each created model, the second model of each session is again created in a shorter period of time compared to the first one. The total duration in the problem understanding phase decrease from 06:06 min in session 1 model 1 to 01:56 min in session 4 model 2.

Figure 74 shows the modeling patterns of subject 4. Almost all possible transitions between the phases are present, except for the transition between the validation and other phase. Compared to the other subjects, there are a lot of method finding and other phases coded. 76% of the transitions started in the method finding phase goes to the modeling/reconciliation phase. 85% of the transitions started in the problem understanding phase go to the modeling/reconciliation phase and 13% of the transitions go to the method finding phase.

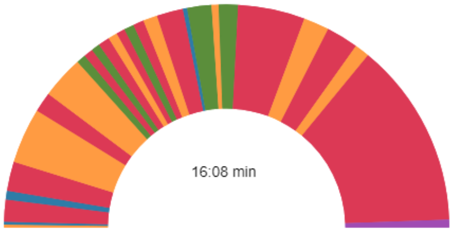
This subject has a consistent modeling strategy during the sessions and had some modeling doubts about modeling parallel activities. The subject was not very confident about his/her modeling capacities and found it challenging to create the BPMN models. The survey answers in table 47 show this as well. The subject answered the question: 'I found it difficult to create the BPMN model' with scores of 3 and 4.

Figure 74: *Modeling patterns Subject 4*



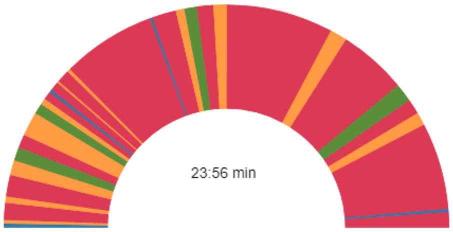


(a) Model 1

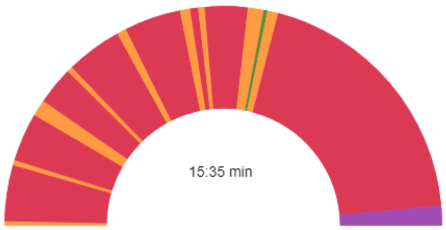


(b) Model 2

Figure 75: Subject 4, Session 1

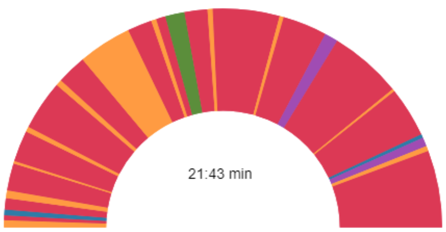


(a) Model 1

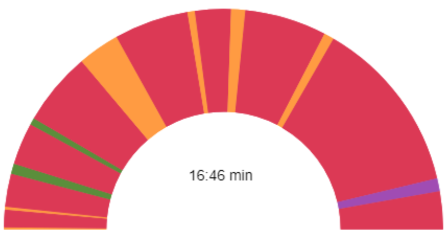


(b) Model 2

Figure 76: Subject 4, Session 2

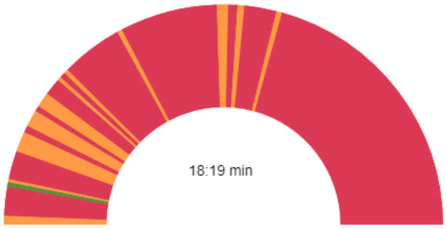


(a) Model 1

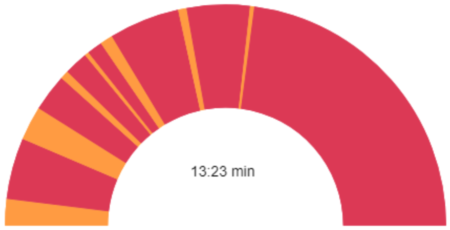


(b) Model 2

Figure 77: Subject 4, Session 3



(a) Model 1



(b) Model 2

Figure 78: Subject 4, Session 4

Figure 79: *Frequency phases Subject 4*

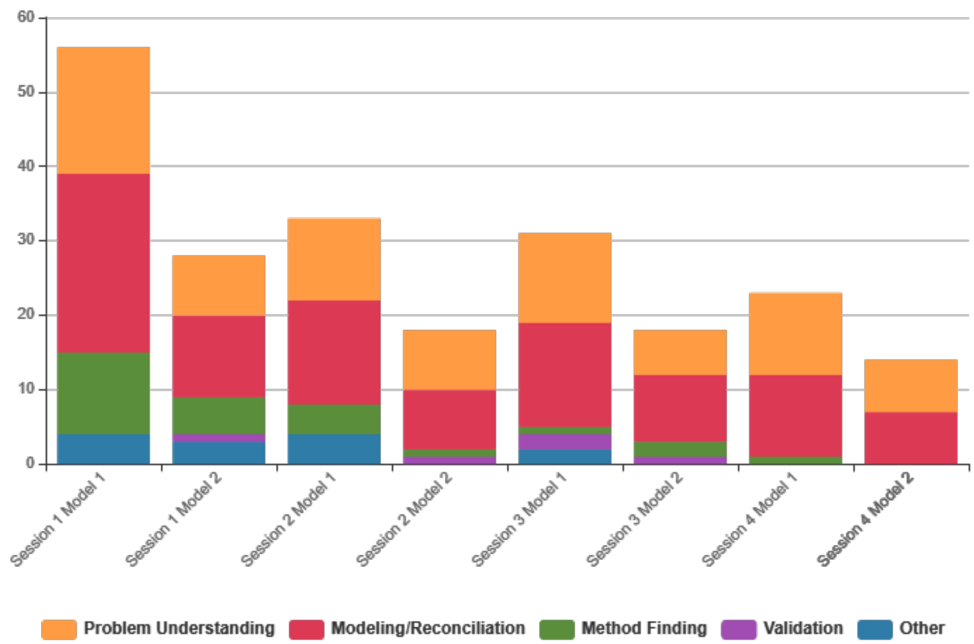


Figure 80: *Time phases Subject 4*

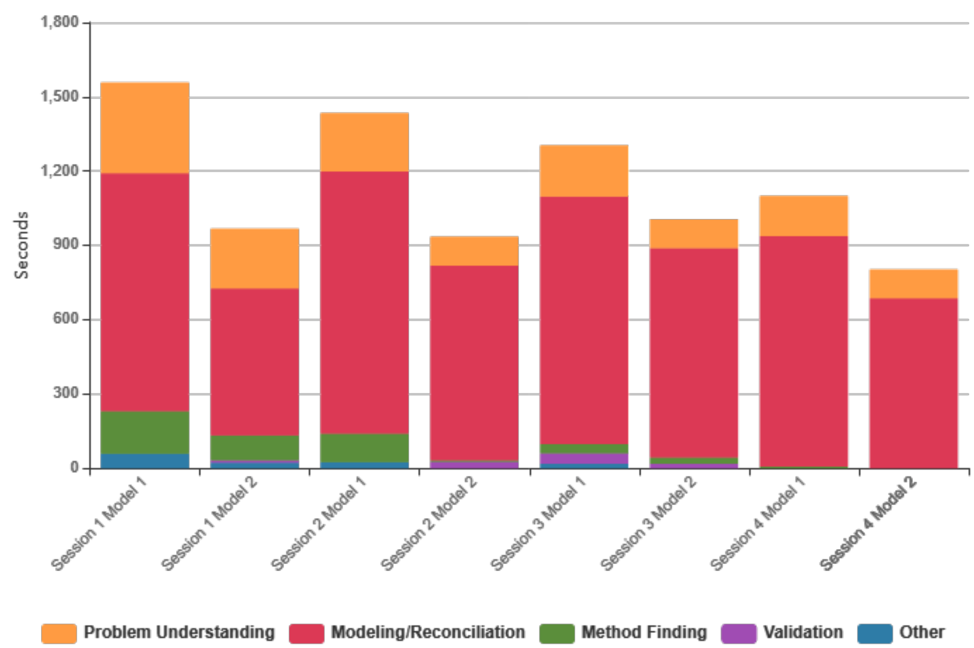


Table 47: Survey answers Subject 4

Vraag	**Session 1**	**Session 2**	**Session 3**	**Session 4**
Welke studie doe je?	Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	1e			
Ik ben goed bekend met procesmodellen.	3	3	4	3
Ik kan procesmodellen makkelijk lezen.	2	3	3	3
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	2	2	3	2
Ik vind mezelf een expert in het maken van procesmodellen.	1	2	2	2
Ik ben goed bekend met BPMN modellen.	3	4	4	4
Ik kan BPMN modellen makkelijk lezen.	3	4	4	4
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	2	2	3	3
Ik vind mezelf een expert in het maken van BPMN modellen.	1	2	2	3
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	1	1	1	4
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	1	2	2	4
Ik vond de beschrijving van proces 1 duidelijk.	4	5	2	3
Ik vond de beschrijving van proces 2 duidelijk.	4	5	4	3
Ik vond proces 1 moeilijk te begrijpen.	2	3	4	4
Ik vond proces 2 moeilijk te begrijpen.	2	3	3	3
Ik vond het maken van BPMN model 1 moeilijk.	4	3	4	4
Ik vond het maken van BPMN model 2 moeilijk.	3	3	3	3

F.5 Subject 5

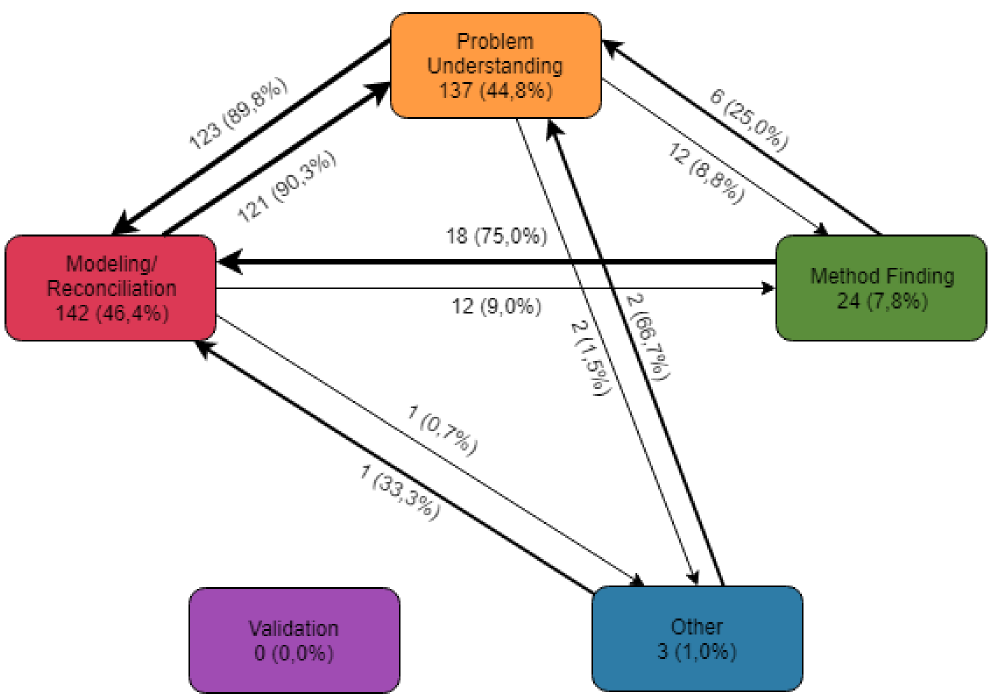
The modeler started in session 1 model 1 with reading the whole textual description first. In the second model of the first session, the subject tried to read a small piece of the textual description before started with modeling. After some modeling actions, the subject decided to read the entire textual description. In the other sessions, the subject read the whole textual description first to get a complete overview of the process. The modeling/reconciliation phases are often interrupted by short problem understanding phases during the process of process modeling. The problem understanding phase is important during the whole process. The textual description is often read multiple times before the modeler understands it and able to translate it to BPMN model elements. Method finding phases are coded in all sessions. In addition, it stands out that the modeler does not check the created model in the validation phase.

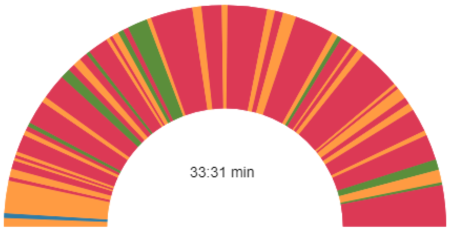
Figure 86 and 87 show the number of phases and the modeling duration. The first model of the first session has the highest number of phases and the longest modeling duration. The method finding phase is coded during all the modeling sessions. Compared to the other participants, this subject spent more time in creating the process models. This subject had the longest modeling duration for 5 of the 8 models.

The modeling patterns are shown in figure 81. There are many transitions between the problem understanding phase and the modeling/reconciliation phase. 75% of the transitions starting in the method finding phase go to the modeling/reconciliation phase. There are no transitions at all to or from the validation phase. Almost all transitions are between the problem understanding, modeling/reconciliation, and method finding phase.

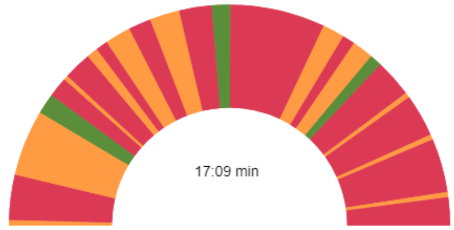
Overall, the modeler creates the process models step by step. All the activities, gateways, and sequence flows are modeled before going back to read the next part of the textual description. The process of process modeling is often interrupted by reconciliation actions to ensure the layout of the model.

Figure 81: *Modeling patterns Subject 5*



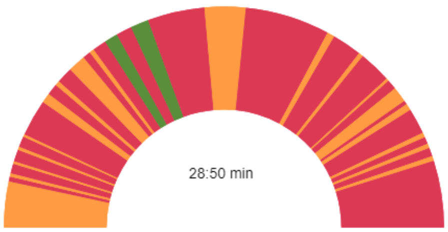


(a) Model 1

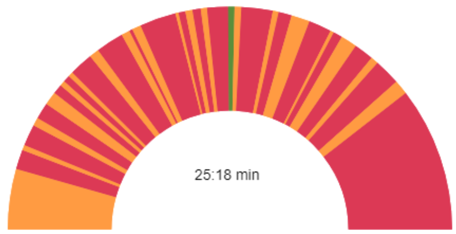


(b) Model 2

Figure 82: Subject 5, Session 1

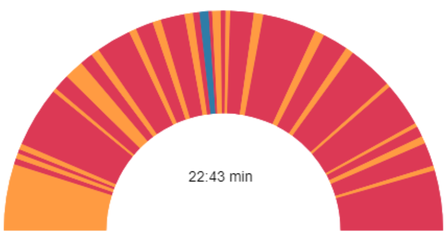


(a) Model 1

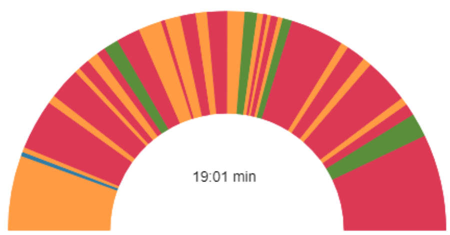


(b) Model 2

Figure 83: Subject 5, Session 2

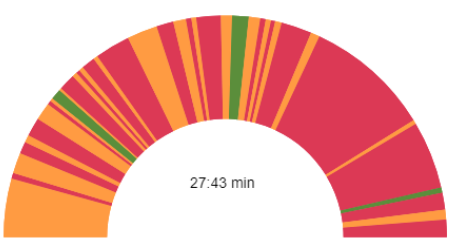


(a) Model 1

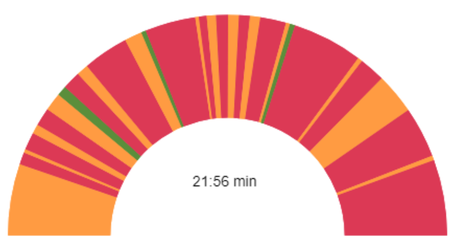


(b) Model 2

Figure 84: Subject 5, Session 3



(a) Model 1



(b) Model 2

Figure 85: Subject 5, Session 4

Figure 86: *Frequency phases Subject 5*

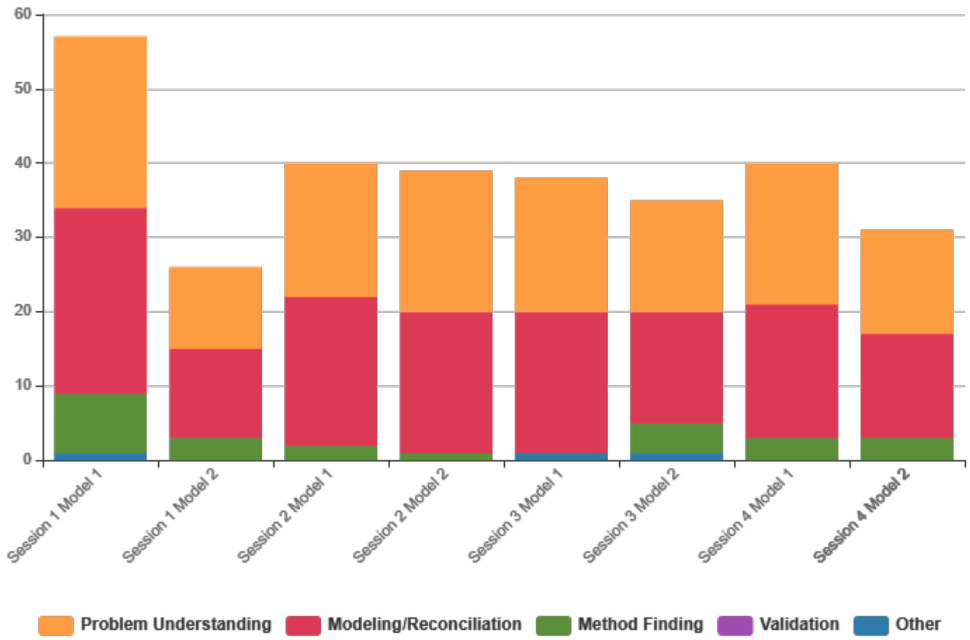


Figure 87: *Time phases Subject 5*

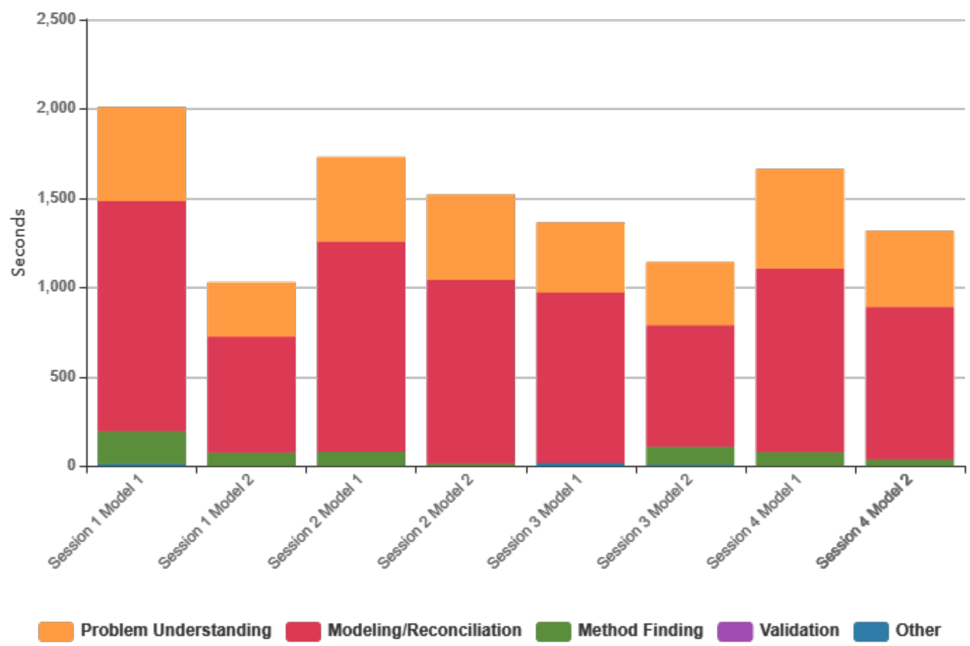


Table 48: Survey answers Subject 5

Vraag	Session 1	Session 2	Session 3	Session 4
Welke studie doe je?	Informatica/ Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	2e			
Ik ben goed bekend met procesmodellen.	4	3	3	3
Ik kan procesmodellen makkelijk lezen.	3	4	4	4
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	3	3	3	3
Ik vind mezelf een expert in het maken van procesmodellen.	2	2	2	3
Ik ben goed bekend met BPMN modellen.	4	4	3	3
Ik kan BPMN modellen makkelijk lezen.	3	4	4	4
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	3	3	3	3
Ik vind mezelf een expert in het maken van BPMN modellen.	2	2	2	2
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	1	2	1	4
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	1	2	1	4
Ik vond de beschrijving van proces 1 duidelijk.	4	5	5	4
Ik vond de beschrijving van proces 2 duidelijk.	4	4	5	4
Ik vond proces 1 moeilijk te begrijpen.	4	2	2	2
Ik vond proces 2 moeilijk te begrijpen.	4	2	2	2
Ik vond het maken van BPMN model 1 moeilijk.	2	3	2	2
Ik vond het maken van BPMN model 2 moeilijk.	2	2	2	2

F.6 Subject 6

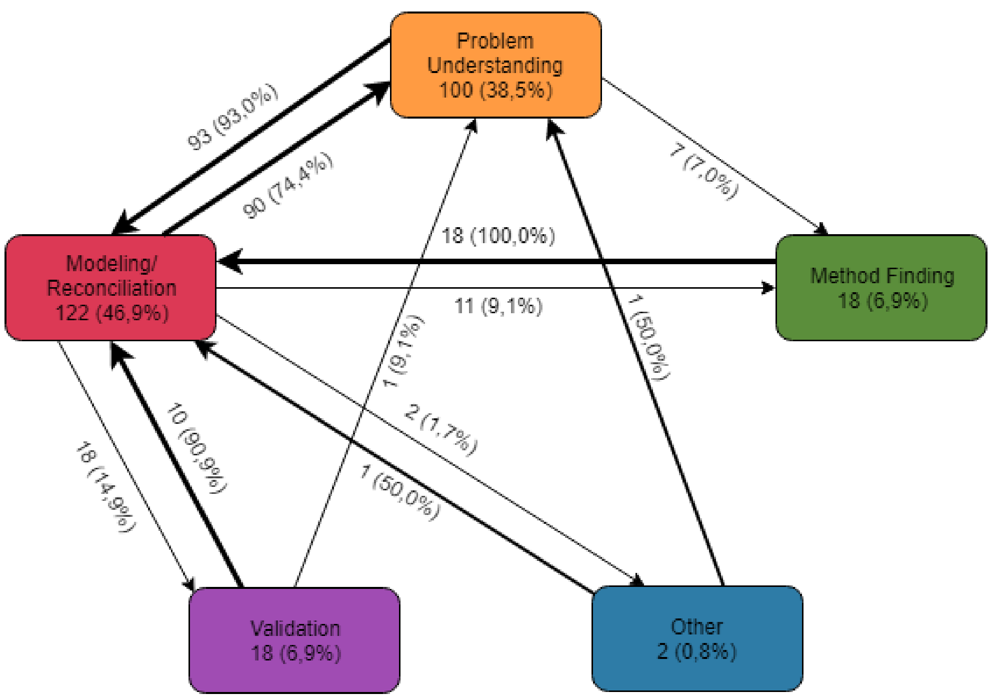
As can be seen in figure 89 to 92, the subject used the same strategy during the modeling sessions. Starting with reading the whole textual description and always end with one or more validation phases. After reading the whole textual description to get a complete overview, the subject modeled the process model in small chunks of modeling/reconciliation steps with always going back to the problem understanding phase to find out the next step of modeling. At the end of each model, the modeler checked the created model for any mistakes and solved the mistakes when needed in the modeling/reconciliation phase.

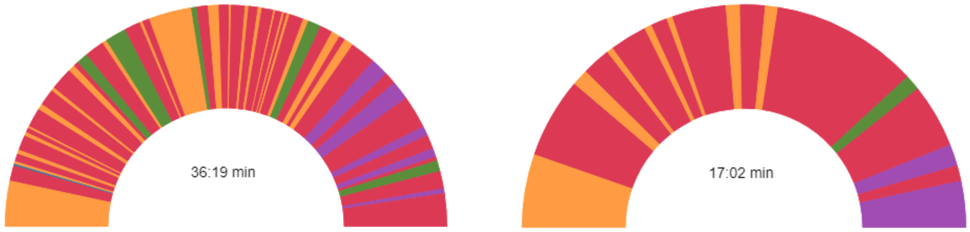
Figure 93 shows the number of phases. The second session of each model always has a fewer number of phases compared to the first one. The first model of the first session has by far the highest number of phases (60) and the longest modeling duration (36:19 min). This is probably due to the fact that the modeler has to get used to the modeling environment and the problem solving task. The maximum validation duration is 3:11 min in session 1 model 1. The minimum validation duration is 01:23 min in session 3 model 1. Except for session 1 model 1 the minimum number of phases is 17 and the maximum number of phases is 39 while the minimum modeling duration is 16:11 min and the maximum modeling duration is 19:41 min. Almost twice the number of phases results in a modeling duration difference of 03:30 minutes.

Almost all transitions starting in the problem understanding phase go to the modeling/reconciliation phase (93%). Almost all transitions starting in the validation phase go to the modeling/reconciliation phase (90,9%). 100% of the transitions starting in the method finding phase go to the modeling/reconciliation phase as well. Almost all transitions starting in the problem understanding, modeling/reconciliation, and method finding phase end in the modeling/reconciliation phase.

As said before, the subject used the same modeling strategy during the sessions. The subject modeled the process models step by step with modeling the activities, gateways, and sequence flows first before going back to the problem understanding phase. The subject always ends with one or more validation phases to check the created model.

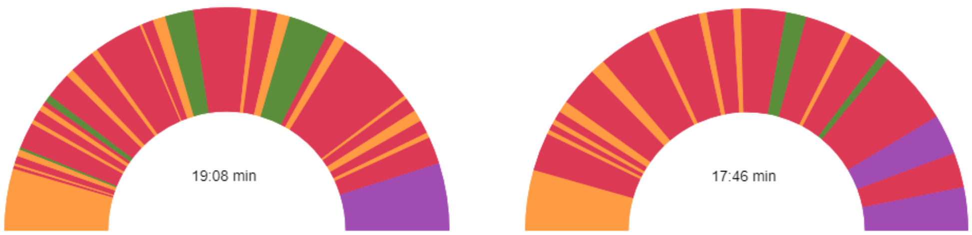
Figure 88: *Modeling patterns Subject 6*





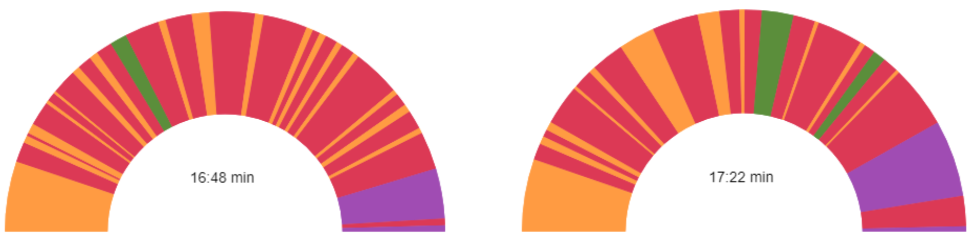
(a) Model 1 (b) Model 2

Figure 89: Subject 6, Session 1



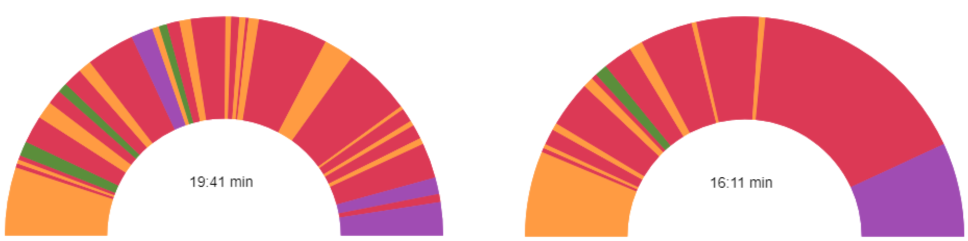
(a) Model 1 (b) Model 2

Figure 90: Subject 6, Session 2



(a) Model 1 (b) Model 2

Figure 91: Subject 6, Session 3



(a) Model 1 (b) Model 2

Figure 92: Subject 6, Session 4

Figure 93: *Frequency phases Subject 6*

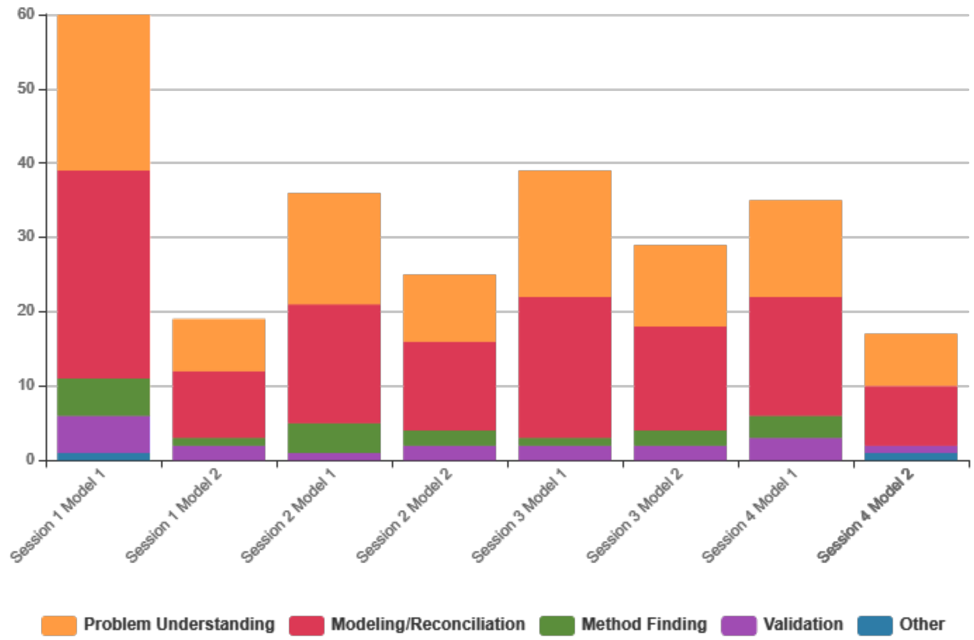


Figure 94: *Time phases Subject 6*

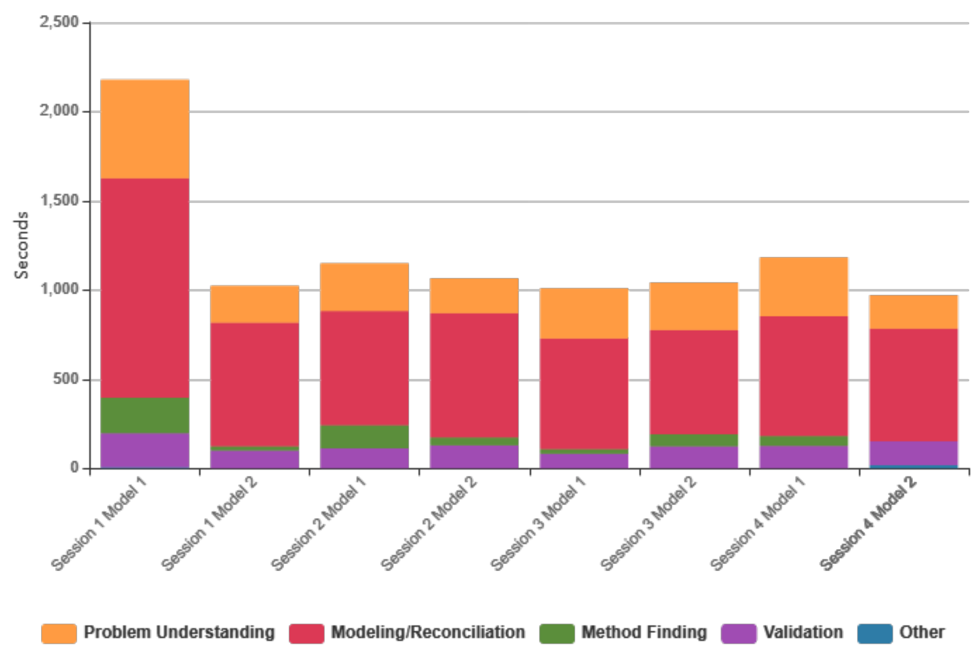


Table 49: Survey answers Subject 6

Vraag	**Session 1**	**Session 2**	**Session 3**	**Session 4**
Welke studie doe je?	Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	1e			
Ik ben goed bekend met procesmodellen.	3	3	4	4
Ik kan procesmodellen makkelijk lezen.	3	4	4	4
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	3	2	4	4
Ik vind mezelf een expert in het maken van procesmodellen.	2	1	4	4
Ik ben goed bekend met BPMN modellen.	3	4	5	5
Ik kan BPMN modellen makkelijk lezen.	4	5	5	5
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	4	4	4	4
Ik vind mezelf een expert in het maken van BPMN modellen.	2	3	4	4
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	2	4	3	5
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	3	3	4	5
Ik vond de beschrijving van proces 1 duidelijk.	4	5	5	5
Ik vond de beschrijving van proces 2 duidelijk.	4	5	4	5
Ik vond proces 1 moeilijk te begrijpen.	2	1	1	1
Ik vond proces 2 moeilijk te begrijpen.	1	1	2	1
Ik vond het maken van BPMN model 1 moeilijk.	2	1	1	5
Ik vond het maken van BPMN model 2 moeilijk.	1	2	2	5

F.7 Subject 7

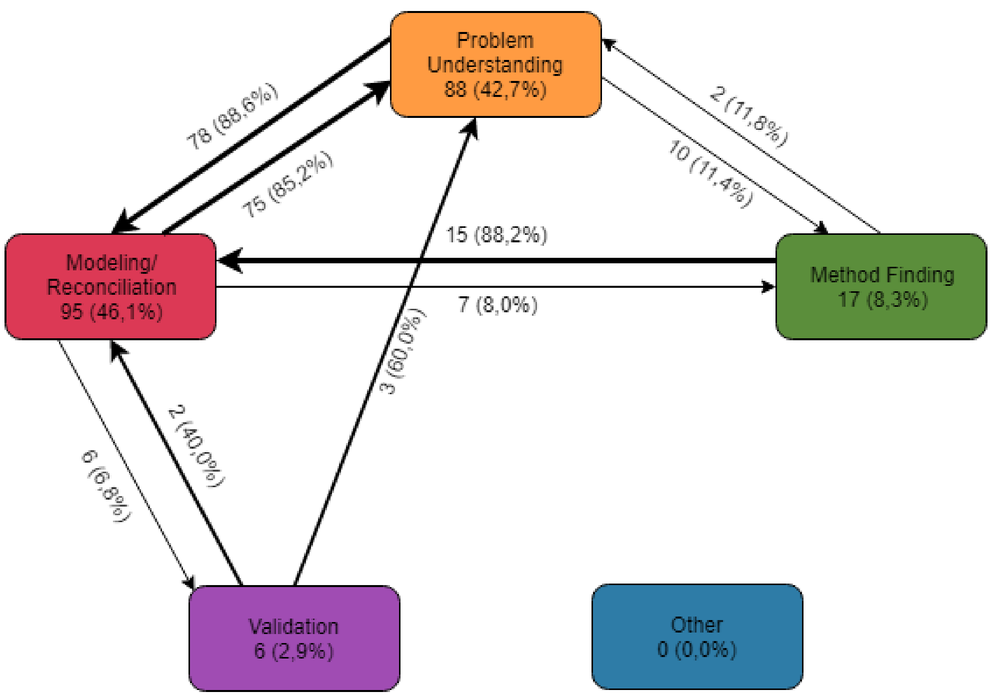
The modeler first reads the whole textual description before moving on to the modeling/reconciliation phase. Large chunks of modeling/reconciliation are combined with shorter chunks of modeling. Except for S1M1, there are method finding phases coded in all models. The subject thinks about the possible modeling options in the method finding phase to find the best way to model the textual description. In session 1 and session 3, there are some short validation phases. In the other sessions, there are no validation phases coded. In S2M2, and s4M2 there are long modeling/reconciliation phases.

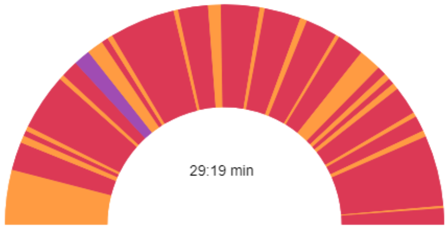
The number of phases is shown in figure 100. The second model of each session contains fewer phases compared to the first model. The subject used in S3M1 the most number of phases (38) compared to 35 phases in S1M1. In S3M1 there are a lot of short problem understanding phases at the beginning of the modeling process. The modeling duration is shown in figure 101. The first model contains the longest modeling duration (29:19 min) compared to 11:23 minutes for S2M2. There is a large variance in modeling duration.

Figure 95 shows the modelling patterns for subject 7. The other phase is not used at all and the validation phase is rarely coded. Most of the transitions are between the problem understanding, modeling/reconciliation, and method finding phases.

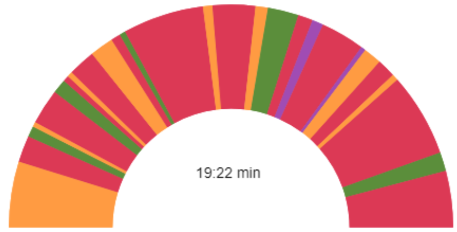
The subject add the modeling elements step by step to the modeling canvas and used the same strategy for all sessions. For more difficult parts in the process, the modeler considers the possible modeling options first, before adding modeling elements. Only in S3M1, two short validation phases are coded.

Figure 95: *Modeling patterns Subject 7*



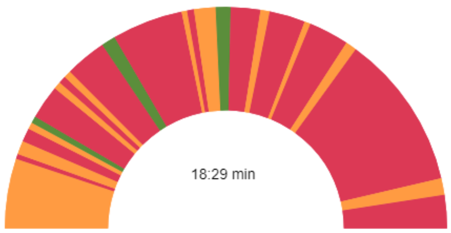


(a) Model 1

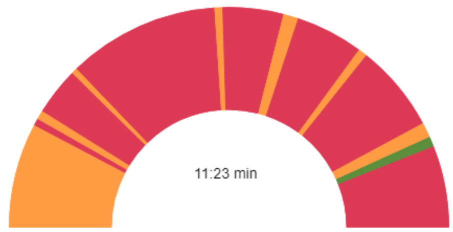


(b) Model 2

Figure 96: Subject 7, Session 1

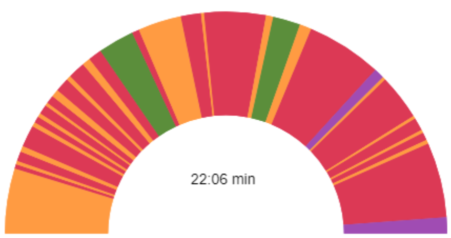


(a) Model 1

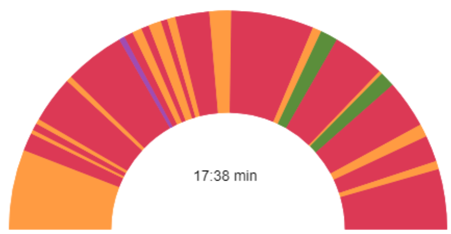


(b) Model 2

Figure 97: Subject 7, Session 2

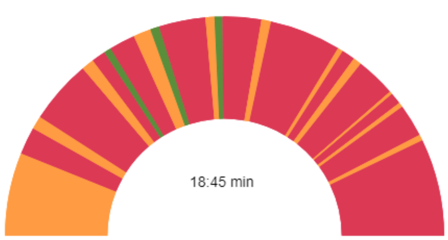


(a) Model 1

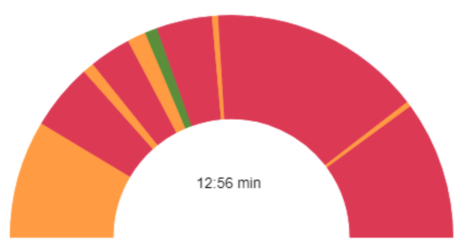


(b) Model 2

Figure 98: Subject 7, Session 3



(a) Model 1



(b) Model 2

Figure 99: Subject 7, Session 4

Figure 100: *Frequency phases Subject 7*

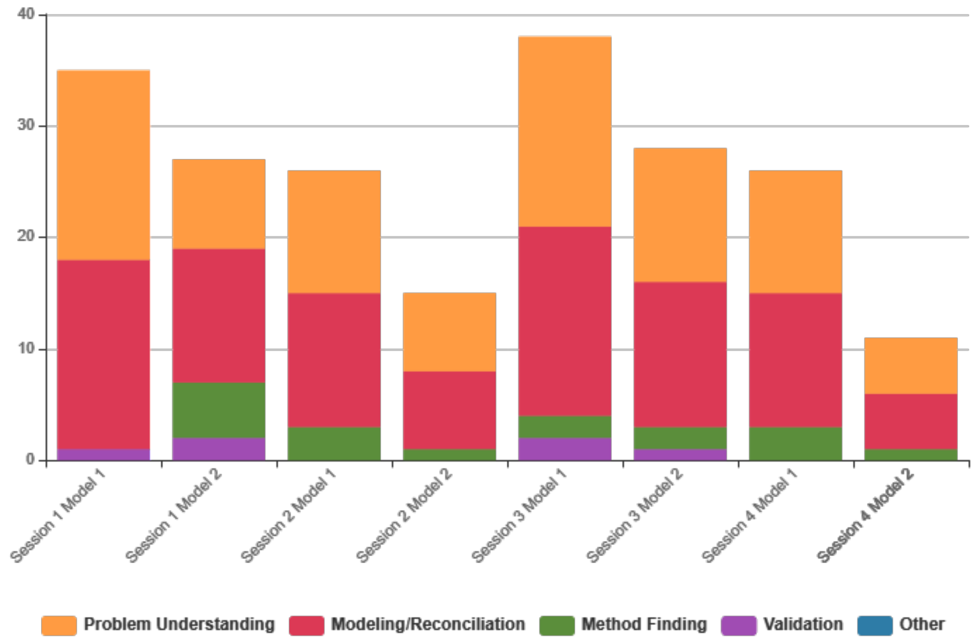


Figure 101: *Time phases Subject 7*

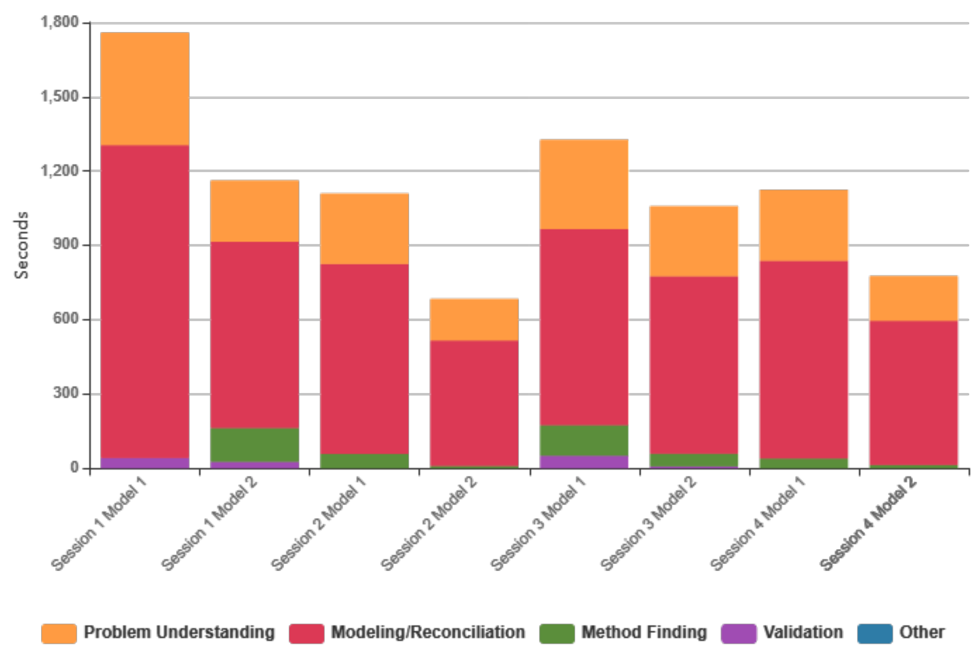


Table 50: Survey answers Subject 7

Vraag	**Session 1**	**Session 2**	**Session 3**	**Session 4**
Welke studie doe je?	Informatiekunde			
Hoe vaak heb je het vak informatiesystemen gevolgd?	1e			
Ik ben goed bekend met procesmodellen.	3	3	3	4
Ik kan procesmodellen makkelijk lezen.	3	3	4	4
Ik vind het makkelijk om een procesmodel te maken aan de hand van een procesbeschrijving.	3	3	3	3
Ik vind mezelf een expert in het maken van procesmodellen.	2	1	1	2
Ik ben goed bekend met BPMN modellen.	3	3	3	4
Ik kan BPMN modellen makkelijk lezen.	4	4	4	4
Ik vind het makkelijk om een BPMN model te maken aan de hand van een procesbeschrijving.	3	3	2	3
Ik vind mezelf een expert in het maken van BPMN modellen.	2	1	1	2
Ik ben bekend met: het aanvraagproces van een hypotheek bij de bank (S1) Scoutingsproces voetballers (S2) Nieuwe wet (S3) Telefoonabonnement (S4)	1	2	2	4
Ik ben bekend met: De taken van een piloot voorafgaand aan een vlucht (S1) Hulp bieden in rampgebieden (S2) Bouwen huis (S3) Taart bakken (S4)	1	1	2	5
Ik vond de beschrijving van proces 1 duidelijk.	4	3	4	3
Ik vond de beschrijving van proces 2 duidelijk.	4	4	4	4
Ik vond proces 1 moeilijk te begrijpen.	2	2	2	3
Ik vond proces 2 moeilijk te begrijpen.	2	2	1	2
Ik vond het maken van BPMN model 1 moeilijk.	4	3	3	4
Ik vond het maken van BPMN model 2 moeilijk.	4	2	3	2

G Results per model

This appendix shows the results per created model. The first figure of each model shows the number of modeling phases. The second figure of each model shows the duration of the modeling phases for all subjects. The same colours are used to represent the problem understanding, modeling/reconciliation, method finding, validation, and other phase.

G.1 Session 1

In the first session of this experiment, the subjects had to create two BPMN models. The first one is the process of a mortgage request. The second model is the process of preparing for take-off of an airplane (appendix B).

Figure 102: *Number of phases S1M1*

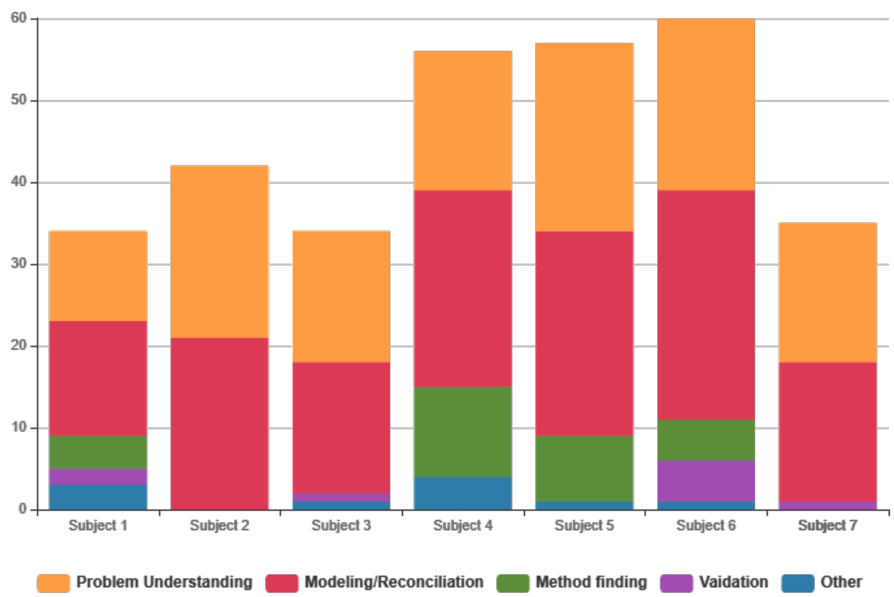


Figure 103: *Duration of phases S1M1*

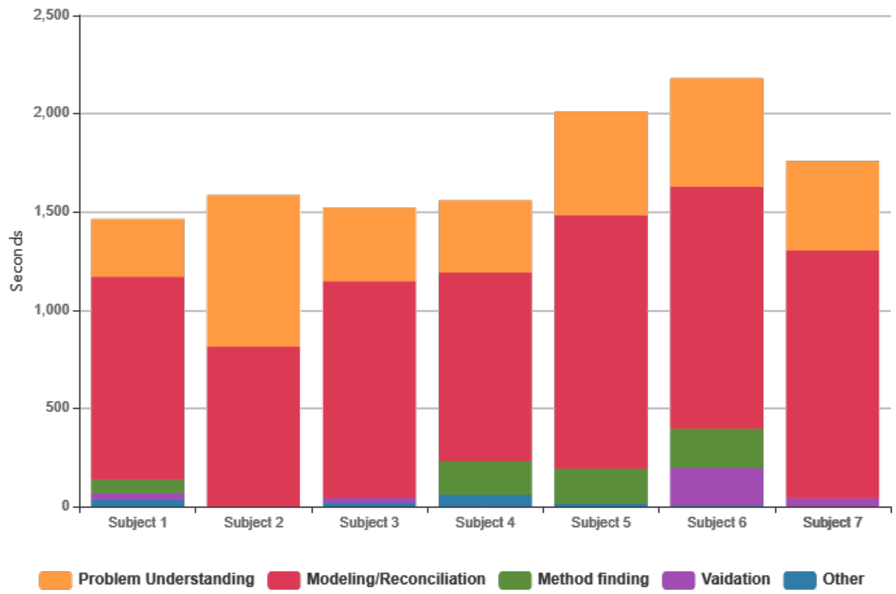


Figure 104: *Number of phases S1M2*

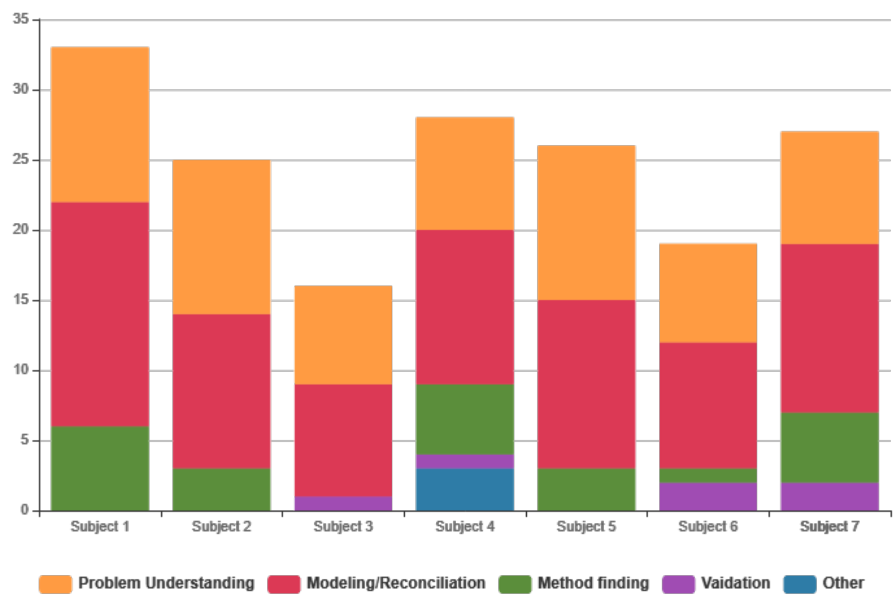
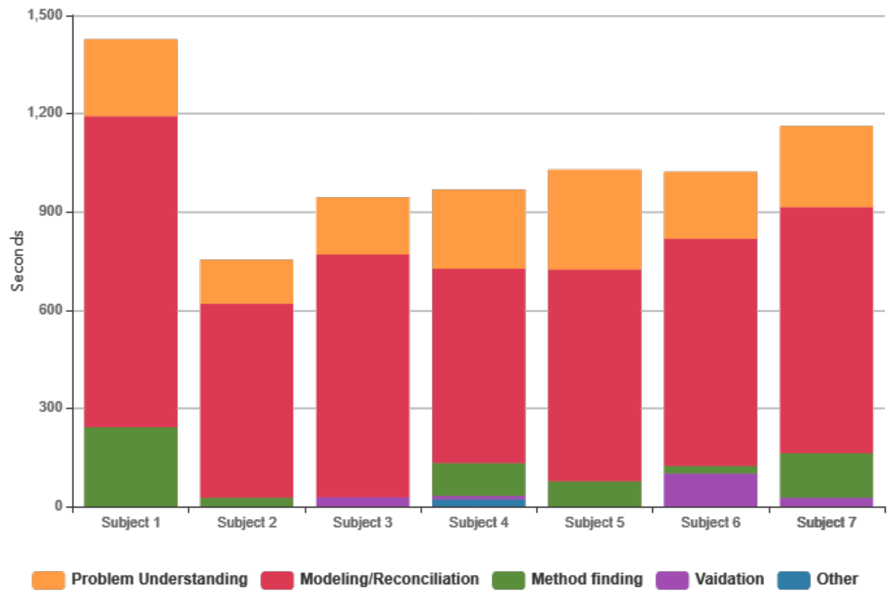


Figure 105: *Duration of phases S1M2*



G.2 Session 2

In the second session of this experiment, the subjects had to create a process describing the scouting process of a soccer player and a process describing aid in disaster areas.

Figure 106: *Number of phases S2M1*

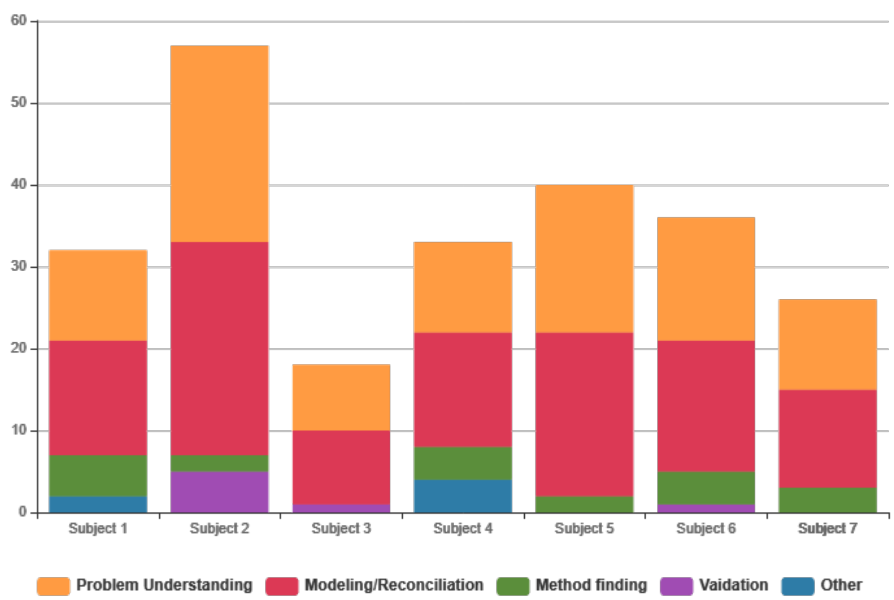


Figure 107: *Duration of phases S2M1*

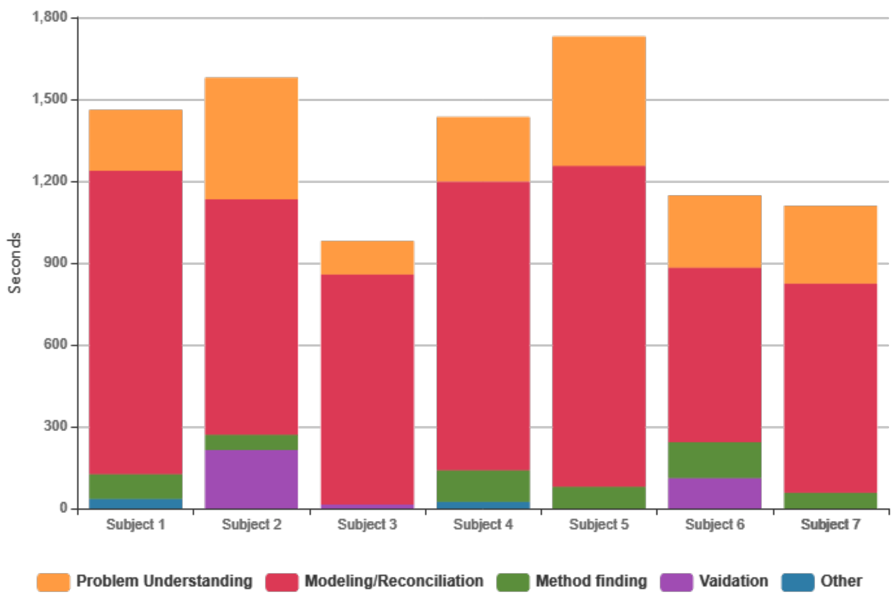


Figure 108: *Number of phases S2M2*

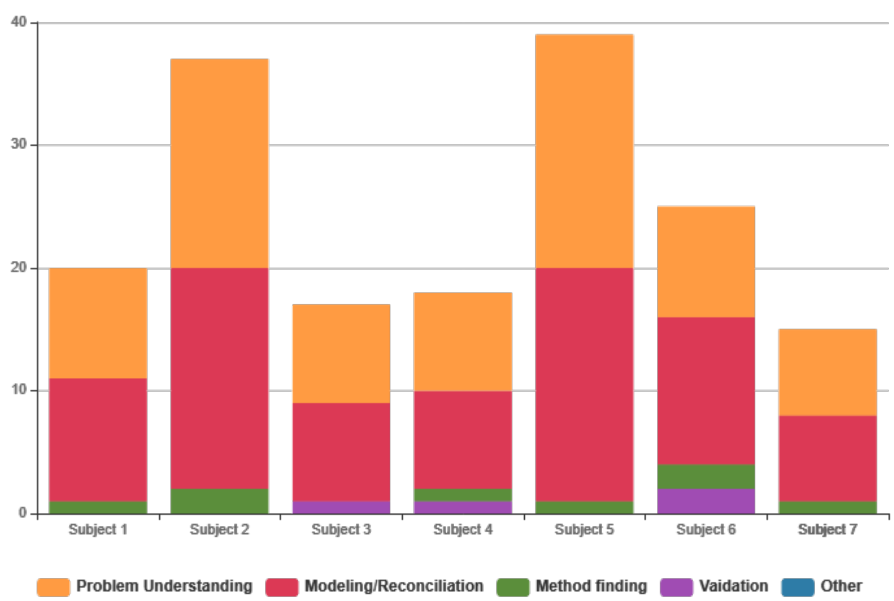
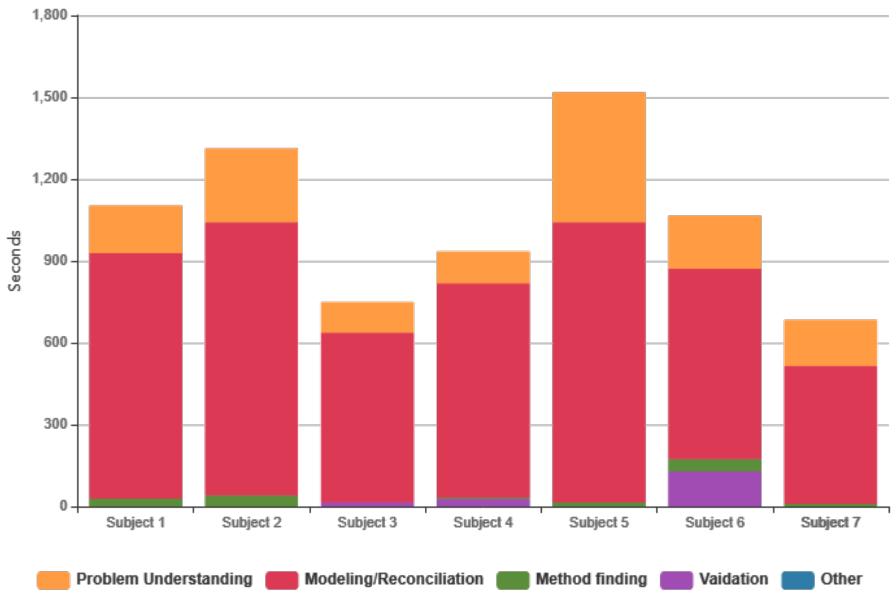


Figure 109: *Duration of phases S2M2*



G.3 Session 3

The first model of the third session describes a legislative proposal. The second model of the third session describes the process of building a house.

Figure 110: *Number of phases S3M1*

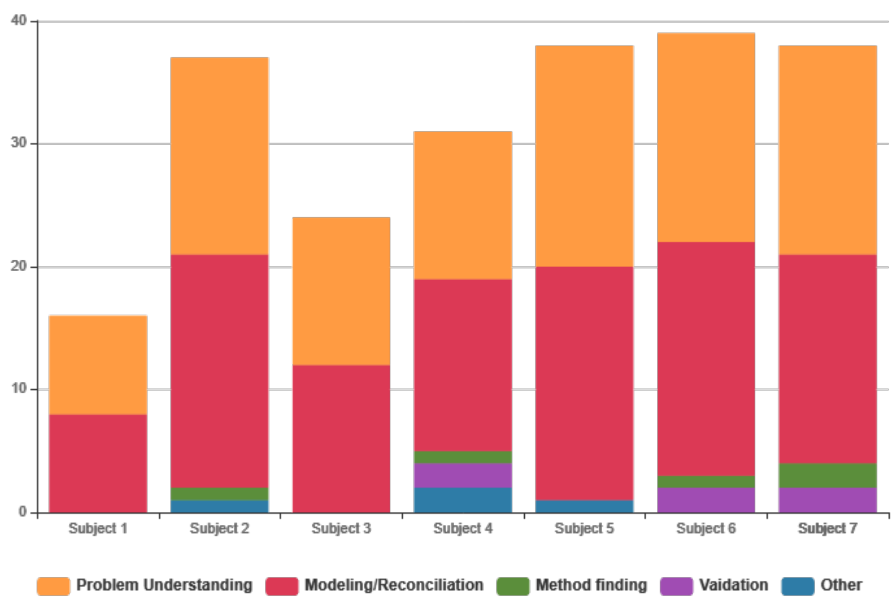


Figure 111: *Duration of phases S3M1*

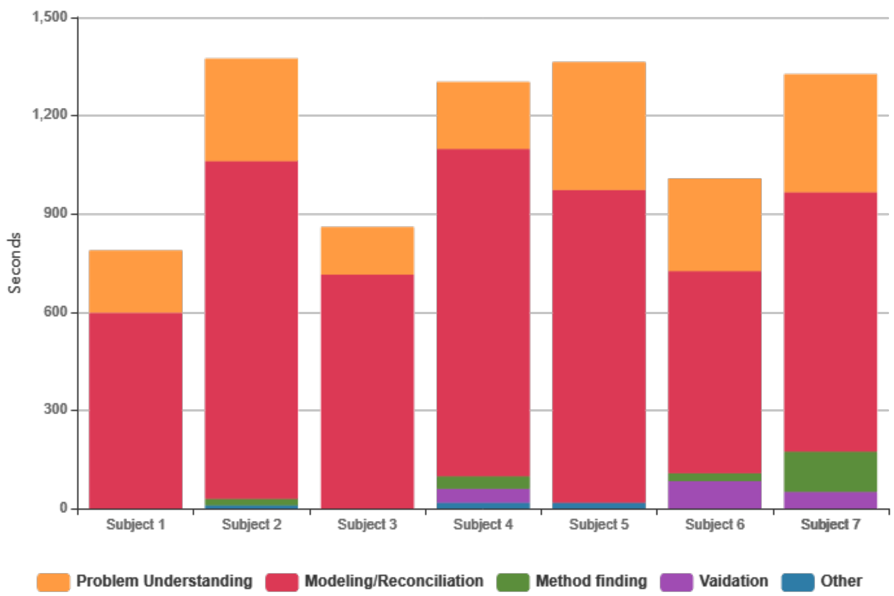


Figure 112: *Number of phases S3M2*

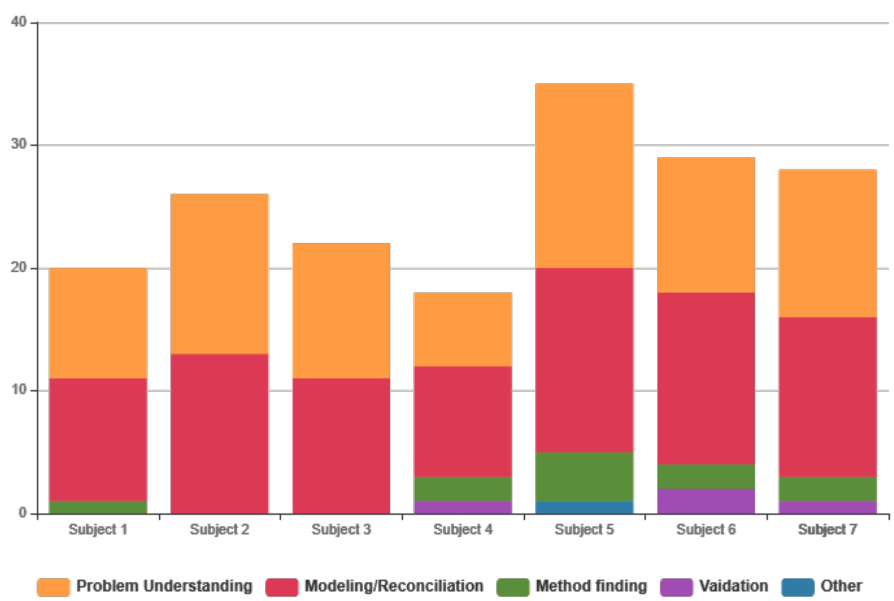
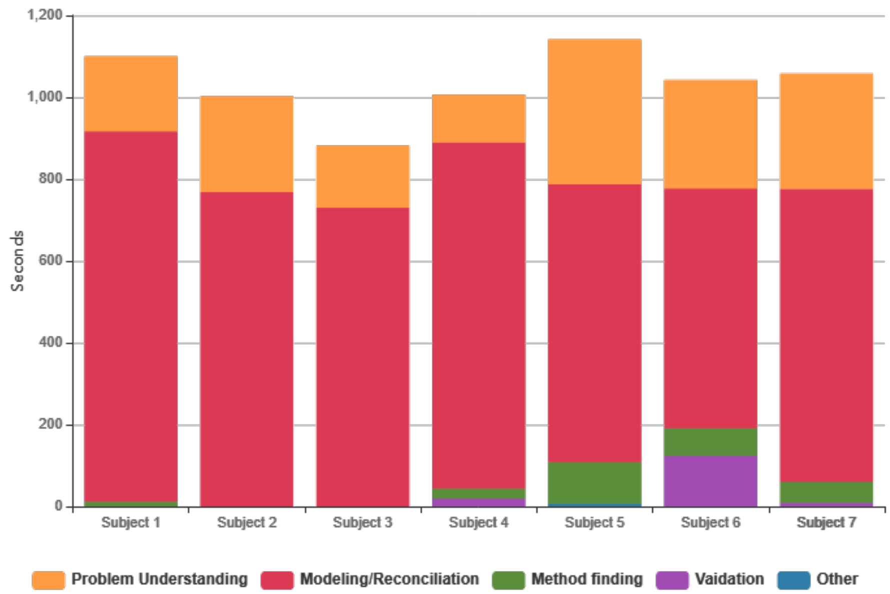


Figure 113: *Duration of phases S3M2*



G.4 Session 4

The first process of the fourth session describes switching to a different telephone provider. The second process describes the preparation of a tarte tatin.

Figure 114: *Number of phases S4M1*

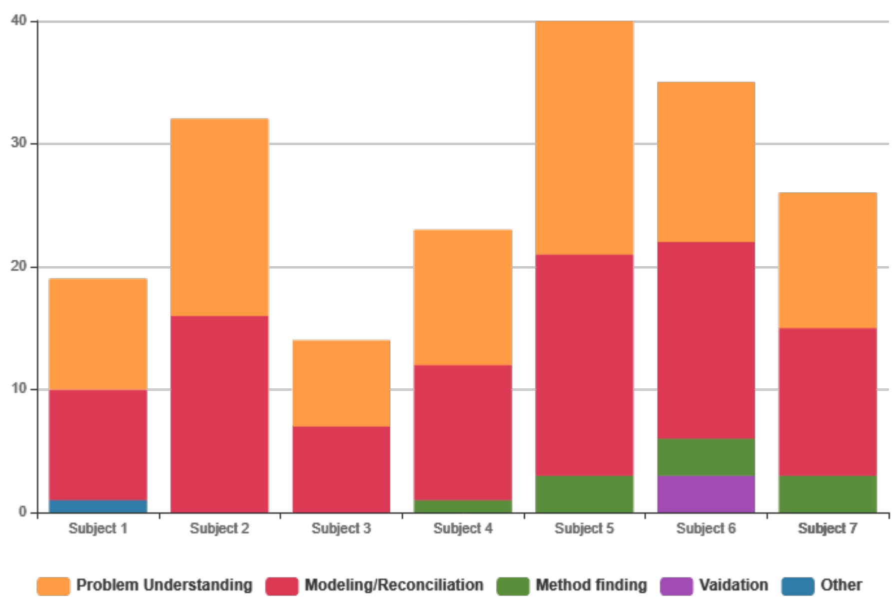


Figure 115: *Duration of phases S4M1*

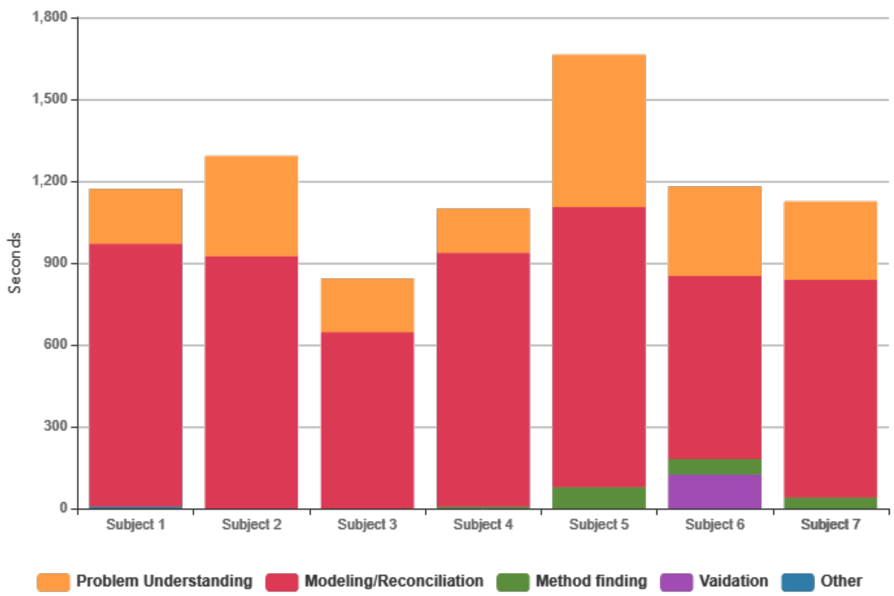


Figure 116: *Number of phases S4M2*

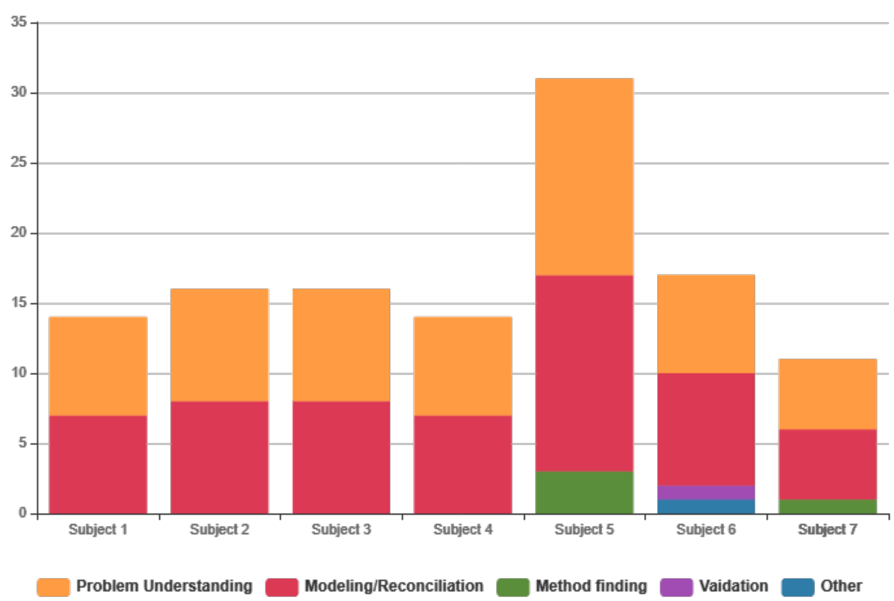


Figure 117: *Duration of phases S4M2*