The Effects of Content Presentation Format and User Characteristics on Novice Developers' Understanding of Process Models

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Abstract:

Process models are used by information professionals to convey semantics about the business operations in a real-world domain intended to be supported by an information system. The understandability of these models is vital to them being used for Information Systems development. In this article, we examine two factors that we predict will influence the understanding of a business process that novice developers obtain from a corresponding process model: the content presentation form chosen to articulate the business domain, and the user characteristics of the novice developers working with the model. Our experimental study provides evidence that novice developers obtain similar levels of understanding when confronted with an unfamiliar or a familiar process model. However, previous modeling experience, the use of English as a second language, and previous work experience in BPM are important influencing factors of model understanding. Our findings suggest that education and research in process modeling should increase the focus on human factors and how they relate to content and content presentation formats for different modeling tasks. We discuss implications for practice and research.

Keywords: process modeling, BPMN, EPC, cognitive theory, experiment

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I. INTRODUCTION

Over recent years, the documentation of business processes has gained attention as a primary focus of modeling in Information Systems practice [Davies et al., 2006]. One key objective of process modeling in Information Systems development projects is to reach a common understanding of how a business works at current (as-is modeling) or how it is supposed to work in the future (to-be modeling) [Burton-Jones and Meso, 2008]. Enabling this common understanding of a business enables developers, for instance, to make decisions in the context of the analysis and design of process-aware Information Systems, service-oriented architectures, and Web services alike [Recker, 2010b].

Our interest in this research is individuals' understanding of a business, and how such an understanding of a business is developed from process models. This is important because any application of process models, for tasks such as organizational documentation, process redesign, workflow specification, systems development, or others, requires first that the involved stakeholders reach an effective and efficient common understanding about the business domain [Aguirre-Urreta and Marakas, 2008].

To examine process model understanding, we draw on Cognitive Load Theory [Sweller and Chandler, 1994] and the Multimedia Theory of Learning [Mayer, 2001] to theorize about three different facets of understanding—surface understanding (understanding the elements of a business domain), deep understanding (understanding the actual and possible relationships among elements in a business domain), and effort of understanding (the resource investment required to understand the domain). We then examine two factors that we predict will influence the understanding of a business that developers obtain from a process model: the content presentation form chosen to articulate the business domain, and the user characteristics of the developers working with the model. Both factors are important elements in the process of constructing knowledge in the modeling process [Gemino and Wand, 2003]. We test our predictions in an experiment with sixty-eight postgraduate Information Systems students.

We proceed as follows. In the next section we review related work. Then, we will introduce the theoretical model and hypotheses. We then describe an experiment we ran to test these hypotheses. Finally, we discuss implications for research and practice and draw conclusions from our research.

II. RELATED WORK

Over recent years, analysts and developers alike have increasingly used process models to assist their decisions about organizational redesign, systems development or workflow implementation projects [Davies et al., 2006]. This is because process models capture, typically in some graphical, semi-formal format, important domain elements, such as the activities that constitute a business process; the performers of these activities; the time, location, and modus of their execution; and the information that is processed [Koschmider et al., 2010]. A variety of so-called process modeling grammars exists that can be used to create process models [Recker et al., 2009].

Arguably, any decision about organization or systems (re)design on the basis of process models is susceptible to the quality of these models. A process model that is incomplete (with respect to the underlying business domain), incorrect (semantically or syntactically), cumbersome to decipher or otherwise deficient will not convey the information about the business domain to the decision maker such that a good decision can be facilitated. In line with the importance of high-quality process models, recent research has investigated several factors attributed to high-quality process models. Studies have, *inter alia,* examined the ontological expressiveness of process models [Recker et al., 2009], or how certain structural attributes (e.g., density, complexity) of the process models affect their quality [Mendling et al., 2010a].

Notwithstanding these research efforts on aspects related to process model quality, to date, there is limited knowledge about how process models are actually understood, that is, how process models can support human communication and problem solving decisions, which are arguably the most important purposes of any graphical modeling effort [Harel, 1988]. This is not to say that no research has been conducted. Mendling et al. [2010a], for instance, report on a set of guidelines for understandable process models based on a set of experiments on process model characteristics such as structure and density. Mendling and Strembeck [2008] show that users' comprehension of process model syntax is dependent on the model structure and the process control flow

knowledge brought to bear by the users. Mendling et al. [2010b] report that the perceptions of users working with a process model are also affected by the format and quality of the textual labels used within the model.

In this study, we seek to extend the body of knowledge in two ways. First, prior studies have typically used a number of comprehension questions to measure process model understandability. Following the distinctions among syntax, semantics, and pragmatics applied by Burton-Jones et al. [2009], we assert that these comprehension questions focused primarily on *syntactical* properties of the model presented—for instance, whether certain routing conditions are lawful, or whether properties such as soundness [Verbeek et al., 2007] or deadlocks [Sadiq and Orlowska, 2000] are being violated. What has been largely neglected so far are measures of the *semantic* properties of the model, i.e., to what extent and how information of the business domain modeled is being understood. In our study, we extend prior research in offering a three-faceted conceptualization, and measurement, of different forms of understanding (surface understanding, deep understanding, and effort of understanding), following prior research in related modeling domains [Gemino and Wand, 2005]. Second, prior studies have typically examined a number of structural properties of the process model as an artifact, such as the number of OR-joins [Mendling et al., 2007], its cross-connectivity [Vanderfeesten et al., 2008], or its modularity [Reijers and Mendling, 2008]. Little knowledge has been established about *pragmatic* factors of the modeling context [Burton-Jones et al., 2009], for instance, how properties of the user working with the model (e.g., his/her experience, his/her domain knowledge) affect his/her understanding, or how different approaches to visualizing a process model (e.g., different process modeling grammars) affects understanding. To that end, we extend prior research by focusing in our work on *user characteristics* and the *content presentation format*.

III. THEORY AND HYPOTHESES

Theoretical Background

Process models are, in their essence, visual representations of a business domain. Visual representations are effective for supporting decision-making about a business domain because they tap into the capabilities of the powerful and highly parallel human visual system [Moody, 2009].

We draw on two related cognitive theories to theorize about domain understanding generated from process models. Cognitive load theory (CLT) [Sweller and Chandler, 1994] defines the cognitive constraints associated with humans. The Cognitive Theory of Multimedia Learning (CTML) by Mayer [2001] provides principles to improve informational messages and promote the development of understanding.

The main assumptions of cognitive load theory are limited working memory and its interaction with a practically unlimited long-term memory [Sweller and Chandler, 1994]. When individuals study new material (e.g., information about a business domain from a process model), they increase their cognitive load, i.e., the burden on their working memory. Working memory has the capacity to process approximately seven items of information at any given time [Miller, 1956]. If prior knowledge exists, however, i.e., if the individuals can use relevant material stored in long-term memory, the cognitive load on their working memory can be reduced, and understanding therewith improved [Sweller and Chandler, 1994].

Following cognitive load theory, there are two sources of cognitive load—intrinsic and extraneous. Reducing one or both of these sources should lead to improved understanding. Our interest is in extraneous cognitive load, which is involved when individuals mentally manipulate the elements in informational material (e.g., a process model) to construct knowledge in their memory (e.g., by locating and mentally arranging the constructs in a process model). This activity involves acquiring the given process model into a mental model and combining the new information with prior knowledge if existent. Cognitive load theory argues that extraneous cognitive load can be reduced when prior knowledge exists, either about the domain (domain knowledge) or about the informational material (e.g., knowledge about the grammar used to depict the process model). This argument suggests, for instance, that model viewers experienced in the content presentation form (for example, the grammar with which the process model is created) should have improved model understanding due to the fact that it is easier for them to combine the new material with their existing knowledge.

While cognitive load theory informs the cognitive constraints to developing domain understanding from a process model, the Cognitive Theory of Multimedia Learning (CTML) [Mayer, 2001] purports to explain the process and the outcome of how individuals viewing explanative material (such as a process model) develop an understanding of the content being presented to them.

Specifically, CTML suggests three elements that are involved in the process of constructing knowledge from explanative information, such as, in our case, process models (see Figure 1):

1. the content of the message, viz., the business content of the process model,

2. the way in which the content is presented, viz., the type of process modeling grammar used to depict the business content, and

3. the individual characteristics of the person viewing the model, viz., the process model user.
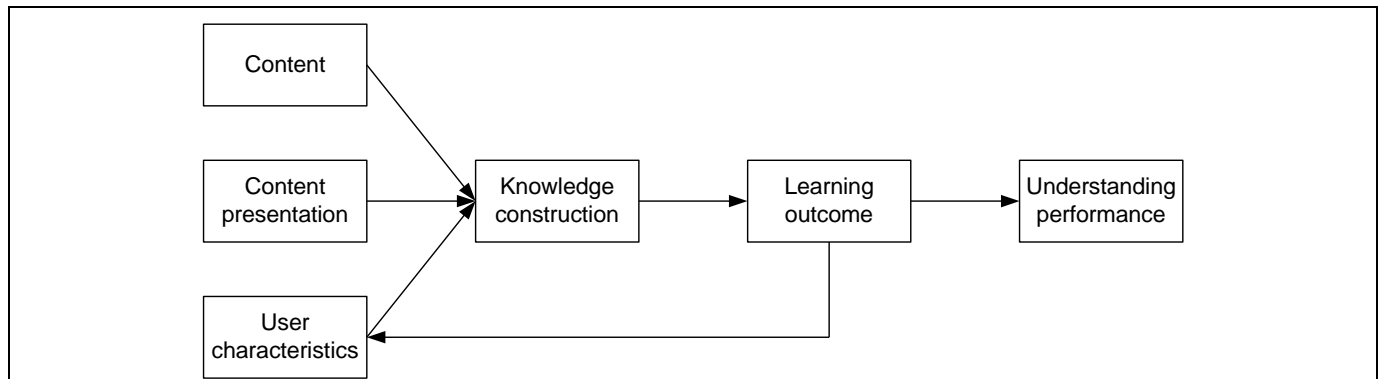
Figure 1. A Model for Knowledge Construction in Process Modeling [Gemino and Wand, 2003]

This conceptualization of the *process* of understanding allows for speculating about the impact of various factors on the development of domain understanding and thereby provides a framework for a series of empirical studies in this area. Also, it allows scholars to reason about the *effort of understanding*, such as the time it takes to complete the process of understanding, from viewing explanatory material (e.g., a process model) to understanding the domain modeled (e.g., by solving domain problems with the help of the model) [Burton-Jones et al., 2009].

CTML further provides means to conceptualize the *product* of understanding. It suggests three outcomes are possible when presenting explanative material: (1) no understanding, (2) surface (or fragmented) understanding, and (3) deep (or meaningful) understanding. These outcomes are primarily based on measures of two variables that Mayer [2001] labels *retention* and *transfer*. Retention is defined as the ability to comprehend the material being presented. Transfer is the ability to use a more meaningful, deeper understanding gained from the material and apply it to problem-solving questions not directly answerable from the material at hand.

No understanding is achieved when both retention and transfer are low. Surface understanding [Burton-Jones and Meso, 2008] is achieved when retention is high but transfer is low. Such a result indicates that material has been received and comprehended but has not been well integrated with prior knowledge. This suggests that memorization has occurred, but not necessarily meaningful understanding. Deep understanding [Burton-Jones and Meso, 2008], on the other hand, is achieved when both retention and transfer are high. High transfer scores indicate that information has been integrated into long-term knowledge and that a deep level of understanding of the presented material has been achieved.

When these premises are applied to the context of process modeling, one key objective for users of process models would be to develop deep understanding, i.e., to be able to develop retention skills as well as transfer skills. Given that a process model is in its essence a visual representation of a real-world business domain, deep understanding will enable a viewer to comprehend the business domain that is depicted in the process model and to reason faithfully and appropriately about associated problems, such as decisions about potential redesign opportunities for the process [Danesh and Kock, 2005], challenges associated with the implementation of appropriate workflow technology [Leymann and Roller, 1997], or the appropriate configuration of a supporting information system [Dreiling et al., 2008]. Comprehension of the process model, a prevalent operationalization of process model understanding to date [Mendling et al., 2010a; Reijers and Mendling, 2011], therefore, addresses only one side of the coin. Our conceptualization of process model understanding extends this work.

Hypothesis Development

On the background of our elaborations above, we develop hypotheses regarding the factors that influence the development of domain understanding from process models. Figure 2 shows our research model. The model proposes that process model understanding (in terms of surface understanding, deep understanding and effort of understanding) is a function of the *content presentation form* (the type of grammar) chosen for creating the process model) and the *user characteristics* of the developer interpreting the model (in terms of command of the English

Figure 2. Research Model
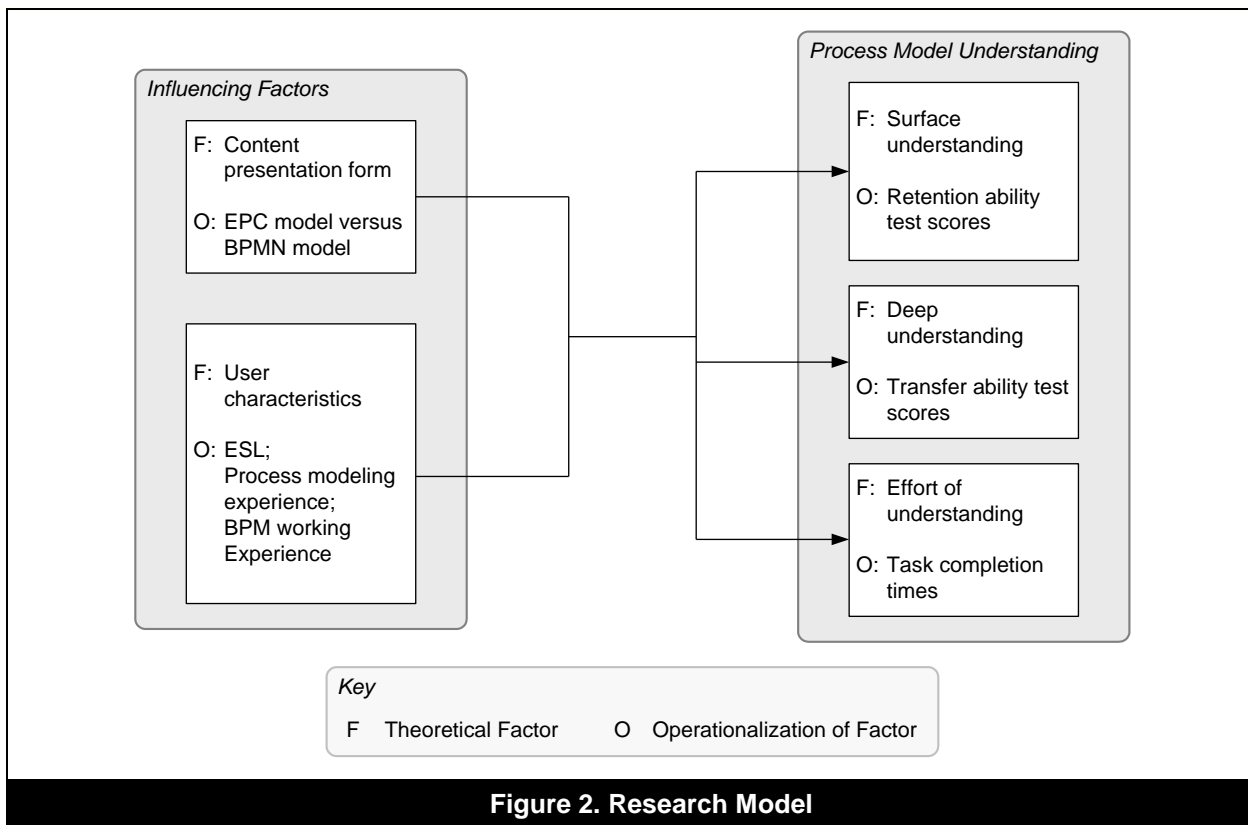
Language, the experience in process modeling, self-believed familiarity, and the number of process models worked with).

Following Figure 2, we theorize that the form of content presentation chosen will impact surface understanding, deep understanding, and effort of understanding.

In process modeling, the content presentation (i.e., the model) is determined by the grammar selected for visualizing a process. A variety of grammars are available for this task. One important aspect in the consideration of a particular grammar is that different grammars have different capabilities for articulating real-world process domains [Recker et al., 2009].

Existing process modeling grammars that could be used for modeling business domains broadly fall into two categories [Phalp, 1998]. Intuitive graphical modeling grammars, such as EPCs, are intended to support capturing and understanding processes for project scoping tasks, and discussing business requirements and process improvement initiatives with subject matter experts [Scheer, 1994]. Conversely, more recent process modeling grammars, such as BPMN, can also be used for advanced purposes such as process evaluation [Dijkman et al., 2008], process execution [van der Aalst and ter Hofstede, 2005], or process simulation [Gregoriades and Sutcliffe, 2008].

To define an appropriate operationalization of the factor content presentation form, we decided to use models created with two different grammars. We selected one grammar that participants were trained in and familiar with. Specifically, we used Event-driven Process Chains (EPCs)—the grammar of choice embedded in the market-leading Architecture of Integrated Information Systems tool suite [Scheer, 1994]. We further used one grammar that participants had no knowledge of, viz., the Business Process Modeling Notation, BPMN—the emergent industry standard for process modeling [Recker, 2010b]. Our main assumption is that an individual that is presented a process model depicted in a grammar she has experience with (in our case, the EPC grammar) should develop higher levels of understanding than someone who is given a process model depicted in a grammar she is unfamiliar with (in our case, the BPMN grammar). The theoretical rationale stems from cognitive load theory [Sweller and Chandler, 1994], which suggests that extraneous cognitive load can be reduced when prior knowledge exists, either about the domain (domain knowledge) or about the material (e.g., grammar knowledge). This argument suggests that model viewers experienced in the content presentation form (the grammar with which the process model is created) should have improved model understanding due to the fact that it is easier for them to combine the new

material with prior knowledge about the grammar existing in their long-term memory. Their extraneous cognitive load is reduced, and hence, learning new information (about the business domain depicted) is improved.

As per this reasoning, understanding is dependent on transfer and retention skills. In light of these arguments, we have:

> H1a: Transfer ability test scores will be higher for the group working with the familiar grammar than for the group working with the unfamiliar grammar.

> H1b: Retention ability test scores will be higher for the group working with the familiar grammar than for the group working with the unfamiliar grammar.

Following Figure 2, we further predict that improved understanding may also manifest in the form of reduced effort of understanding. This means that participants may achieve similar scores in transfer ability or retention ability tests, yet may be able to infer the correct answers more quickly.

Cognitive load theory suggests that a model that is represented using a grammar that participants received prior training in requires only reduced cognitive effort, which, in turn, may manifest in less time required to infer information from the model. In other words, understanding occurs faster because the cognitive load is decreased because the integration of the information material contained in the "familiar" model can occur more easily and quicker. Therefore, we have:

> H1c: Transfer ability test tasks will be completed faster by the group working with the familiar grammar than for the group working with the unfamiliar grammar.

> H1d: Retention ability test tasks will be completed faster by the group working with the familiar grammar than for the group working with the unfamiliar grammar.

Next, following Figure 2, we consider the impact of user characteristics on the impact of the content presentation form on model understanding. Development of domain understanding from process models is essentially a cognitive process and, therefore, influenced by the levels of experience and knowledge brought to bear by the individual working with the models. We concentrate our examination of user characteristics to three variables identified as relevant in studies of modeling in other domains (data and object-oriented modeling). Table 1 gives an overview of the characteristics studied, the measures used and their previous applications in related studies.

Table 1: User Characteristics Considered in Prior Work		
User characteristics/measure	Possible values	Previous
English as a second language	Yes/No	Masri et al., 2008
Experience in process modeling	Number of models created and/or viewed	Davies et al., 2006
Work experience in business process management	Yes/No, and description of work experience	Masri et al., 2008

Masri et al. [2008] uncovered in their experiment on data modeling an interesting interaction effect stemming from the role of English as a second language (ESL). They reported significant differences in task scores between experiment participants with English as primary as opposed to secondary language. While process models are composed of graphical constructs to articulate domain semantics, the models are also annotated with textual labels—be it the nature of an important business event or the exact type of task to be performed in a process model. Masri et al. [2008] conclude from their findings that working on a modeling exercises in a foreign language can lead to additional sources of intrinsic cognitive load. Cognitive load theory suggests that ESL users are exposed to higher overall cognitive load compared to those working in their native language. Therefore, we view ESL as one potential impediment of process model understanding, and the effort that goes with developing such an understanding. Formally, we state:

> H2a: The use of English as a second language will have a negative effect on transfer ability test scores.

> H2b: The use of English as a second language will have a negative effect on retention ability test scores.

> H2c: The use of English as a second language will have a negative effect on transfer ability test completion times.

> H2d: The use of English as a second language will have a negative effect on retention ability test completion times.

Prior research further suggests the importance of prior experience to model understanding [Khatri et al., 2006]. Process modeling is essentially a problem-solving activity where humans create models of a business domain to aid them with tasks such as information systems analysis, organizational re-design, simulation, requirements specification, and others. Newell and Simon [1972] conjecture that experience is an important factor in such problem-solving activities. Experienced modelers possess chunks and schemas of knowledge, manifesting in a repertoire of work-arounds, for modeling problems they encountered before. Such situations have been noted in various process modeling studies [Recker et al., 2010], and we thus deem experience an important user characteristic to study.

Khatri et al. [2006] differentiate experience with a method (such as a process modeling grammar) from experience in a domain (such as business process management). The former is typically measured by considering the number of process models created or studied by an individual, as an indication for how often a respondent has actually been confronted with process modeling. In terms of domain experience, previous work experience in process management suggests that individuals have had a high level of exposure to concepts pertinent to process specification, process redesign or process-oriented information system development as part of their work experience. This experience could give these developers an advantage over less experienced developers, in that they would show a better understanding of general concepts and notions pertaining to the process paradigm.

In both cases, experience in domain or method essentially lowers the intrinsic cognitive load on the model reader, because prior knowledge is available in the long-term memory that can assist the working memory in arranging process model contents into the mental model, and then assessing this mental model to reason about the understanding generated. Cognitive load theory suggests that the positive effects of the decreased cognitive load, therefore, could assist in the assimilation of model information into a mental model, which would manifest in improved understanding and decreased effort of understanding. Accordingly, we state:

H3a: Higher modeling experience will have a positive effect on transfer ability test scores.

H3b: Higher modeling experience will have a positive effect on retention ability test scores.

H3c: Higher modeling experience will have a positive effect on transfer ability test completion times.

H3d: Higher modeling experience will have a positive effect on retention ability test completion times.

H4a: BPM work experience will have a positive effect on transfer ability test scores.

H4b: BPM work experience will have a positive effect on retention ability test scores.

H4c: BPM work experience will have a positive effect on transfer ability test completion times.

H4d: BPM work experience will have a positive effect on retention ability test completion times.

IV. RESEARCH METHOD

Because this is the first test of the theoretical model in the process modeling domain, we chose to use an experimental method because it affords a higher internal validity than other methods [Cook and Campbell, 1979].

Design and Measures

We used a between-groups design with one treatment: EPC versus BPMN process model content presentation form. To manipulate the treatment variable, we considered two real-life process scenarios, *Goods receipt* and *Claims handling,* which were provided by an insurance company engaging in process specification and redesign projects. We deemed these cases to be adequate experimental treatments given that the cases reflect modeling scenarios typically encountered in real-life process modeling practice. We created two different process models of each scenario, one using the EPC grammar, one using the BPMN grammar. The Appendix shows the materials used for the Goods receipt case.

We employed four dependent variables: To measure transfer abilities, we used as a measure scores achieved on an *inferential problem solving* test. Inferential problem solving scores are a measure of transfer ability because these questions require reasoning about the domain where the answers are not directly represented in the model [Mayer, 2001]. Specifically, we measured transfer ability by giving the participants three business scenarios based on the business domain depicted in the process models and asking them to provide plausible solutions to the problem presented in the scenario. We have selected inferential problem solving tasks over model-based problem solving tasks (questions that can be answered by considering the graphical model only) because in industry practice, process models are mostly used as an organizational documentation tool to communicate information about organizational procedures, related business rules, and policies to operational staff. In their business transactions,

these staff are then often required to use these models when making decisions about single transactions or business cases, i.e., to solve transactional problems of their business processes based on the general information about the process as depicted in the model.

In developing scores for these questions, we followed the guidelines of Bodart et al. [2001] and distinguished three types of answers:

1. the number of plausible answers based on information inferable from the model,

2. the number of plausible answers that showed knowledge beyond the information provided in the model, and

3. the number of implausible or missing answers.

On basis of these three types of answers, we are able to distinguish inferential transfer capabilities—answers of type 2—that involve deep cognitive processing from problem solving capacities that are characterized by elaborative transfer capabilities [Bodart et al., 2001, p. 403].

To measure retention abilities, we used scores achieved on a *Cloze* test [Taylor, 1953], similar to the studies conducted in Gemino and Wand [2005] and Masri et al. [2008]. In a Cloze test, participants receive a textual passage to read in which some of the words are missing and need to be filled in. The more blanks filled in, the better the understanding of the *meaning* of the missing word, with focus placed on the semantics of the overall passage [Greene, 2001]. In our case, the Cloze tests consisted of a textual description of the processes depicted in the models the participants viewed beforehand, with some of the words missing. Participants were asked to fill in the blanks based on their understanding of the process model. High scores in this test would indicate a high level of retention of the semantics of the business domain depicted. This is because a Cloze test can be seen as a measure of the abilities of a participants to recall the semantics conveyed in the model that he does not have access to anymore, viz., to display retention capacity.

To measure effort of understanding, we recorded the *task completion times* for both the transfer and the retention ability tests. Participants were informed that task completion times would be recorded but were given as much time as needed to complete their tasks. For manipulation check purposes, we also collected data on the *perceived ease of understanding* each of the models as part of the post-test, using the four-item Likert scale developed by Gemino and Wand [2005].

Last, we used a *model comprehension test*, to be able to conduct manipulation checks between the treatment groups. When conducting experiments about different types of content presentation forms (different types of process models), it is adamant to establish that the models enable a meaningful comparison. Therefore, following Burton-Jones et al. [2009],, we sought to collect evidence that the EPC and BPMN models used in our study approximately contain the same amount of information. We followed Gemino and Wand [2005] and Masri et al. [2008], and used as evidence a multiple-choice comprehension test. The questions in such a test are solely focused on the elements provided in the models, i.e., solely on information that is directly available from the graphical model. If the models are roughly equivalent treatments, both groups should score similarly in the comprehension tests. Therefore, we used a set of multiple-choice questions, in which participants were asked to judge basic features of the process model presented. For each question, participants were instructed to fill in "Yes," "No," "Undecided," or "Cannot be answered from the model."

To measure user characteristics, we collected several demographic data during the pre-test. For manipulation check purposes we collected data on self-believed grammar familiarity using the three item-scale developed by Recker [2010a]. We further collected demographic data (use of English as a second language, gender) about the participants. To measure previous relevant work experience, we asked participants to report on a Yes/No scale about their work experience, and, in the positive case, to briefly describe type and nature of their experiences. To measure modeling experience with the EPC grammar, we asked participants to estimate the number of EPC models created or read. We also recorded modeling experience in terms of the months spent working with a grammar, following Mendling et al. [2010a].

Participants

In the experiment, sixty-eight postgraduate Information Systems students participated. We selected students over practitioners, because the experimental results could have been confounded by participants that are able to bring to bear prior business knowledge in one of the business domains [Siau and Loo, 2006]. Previous research indicates that experiment participants with high domain or modeling grammar knowledge may have difficulty in overcoming developed expertise leading to biases [Shanks, 1997; Lee and Truex, 2000]. Also, student populations have been

argued to be adequate proxies for novice developers [e.g., Burton-Jones and Meso, 2008], the cohort of interest in our study.

Instead of providing instruction in a grammar immediately prior to the experiment, we considered students that had previously completed a postgraduate course on business process modeling with the EPC grammar, similar to Sinha and Vessey [1999]. This allowed us to ensure that all participants had a thorough (as opposed to superficial or high-level) understanding of the EPC grammar. None of the participants had any knowledge of the BPMN grammar.

Participants were randomly assigned to one of two treatment groups. Participation was voluntary and as incentives the students were upfront offered the chance of participating in a draw for one of several course books. The test was monitored to assure individuals completed the test independently.

Materials

The experiment material consisted of an information cover sheet with consent form, one page of directions, two model cases, "Goods receipt" and "Claims handling," and several sheets with questions and textboxes for answers. The models of the two cases differed in their apparent complexity [Gemino and Wand, 2003], i.e., in the number and semantics of constructs in the model. Table 2 summarizes the differences between the models and highlights the differences between EPC and BPMN in respect of the apparent complexity of the models produced. Examples of the experimental material used (for the Goods Receipt case) are listed in the Appendix. All other material used is available from the contact author upon request.

Table 2: Complexity of the Process Models for Each Case				
Measure	Goods receipt EPC	Goods receipt BPMN	Claims handling EPC	Claims handling BPMN
Number of grammar constructs overall	27	27	44	36
Number of semantically different grammar constructs	7	10	6	13

Procedures

The experimental procedure began with a pre-test of domain knowledge and modeling experience. Then, each participant completed the case *Goods receipt* and then *Claims handling.* One treatment group first received a model depicted in the grammar they are familiar with (i.e., EPC), the other group first received a model depicted in the unknown grammar (i.e., BPMN). In the experiment, the two groups then received a model in the other grammar (i.e., BPMN for the group that used EPCs first, and vice versa).

By using two cases (goods receipt and claims handling), our research design allowed us to replicate our findings in different settings, thereby providing a stronger test of our hypotheses than would have been possible with a single model case only. Table 2 shows that in the second case (claims handling), the apparent complexity of the models increased, thus increasing the cognitive burden on the model viewer. This was done to increase the strength of the treatment variable (the differences in the content presentation form), so as to avoid type-2 error.

For each of the two cases, participants completed three tasks in the following order: model comprehension, inferential problem solving, and Cloze test. Task completion times were recorded. A post-test was provided after the Cloze test of the second case to measure perceived ease of understanding associated with the grammar used. A subsequent ANOVA procedure showed that case order did not affect test scores.

V. RESULTS

Two research assistants were employed to code the responses received from the experiment. These research assistants were not informed about the purpose of the study to ensure coding independence. To establish coding reliability, both research assistants first individually coded the responses and then met to defend and discuss their coding to generate a final, consensually agreed coding result. After the individual response coding, we calculated a Kappa statistic of 0.84, which suggests excellent inter-coder reliability [Landis and Koch, 1977]. After discussion and consolidation, the agreement was 100 percent.

Differences in Transfer Abilities

We speculated in Hypothesis H1a that deep understanding (in terms of transfer abilities) would be higher for the group of users confronted with EPC models with which they were familiar. We speculated in Hypothesis H2a that ESL would have a negative effect on the transfer test, and in H3a and H4a that participants with higher levels of modeling and BPM experience would score higher.

Hypothesis testing was completed using a multiple analysis of covariance (MANCOVA) technique and performed with SPSS Version 16.0 [Stevens, 2001]. We used the binary variable *type* as independent factor to separate the EPC model group from the BPM model group.

As covariates, first, we considered the binary variable *ESL*. Our pool of participants consisted of twenty-one native English speakers and forty-seven non-native speakers (European and Asian).

Second, in terms of previous relevant work experience, we had twenty-two participants with process-related work experiences in projects such as enterprise application integration, business process redesign, introduction of ERP software, IS development, and process documentation.

Third, in terms of modeling experience with the EPC grammar, we asked participants to estimate the number of EPC models created or read. Answers given ranged from 1 to 500, with a median of 15. We created a 0/1 dummy variable by dividing respondents into two groups, above (n = 36) and below (n = 32) the median.

As dependent measures, we used the inferential scores (*true* transfer scores) for both model cases, i.e., the answers that were coded as displaying true transfer abilities and providing problem solutions beyond the mere content of the models. We also used the scores obtained for the number of plausible answers based on information inferable from the model (*model-based* transfer scores), to be able to contrast the results.

We first checked whether the data met the assumption of equal variances in the dependent measures across groups. Levene's test was insignificant for both cases (F = 1.53, p = 0.14 for case one and F = 1.43, p = 0.18 for case two), indicating that the data met this assumption. Table 3 gives the descriptive results and Table 4 gives the results from the statistical tests. Significant results are highlighted gray.

Table 3: Descriptive Results of Transfer Ability Test Scores					
Dependent Variable	Group	Means	St. Dev.	Means	St. Dev.
Transfer ability scores (acceptable inferential answers)	EPC (n = 34)	1.65	1.18	1.47	1.21
	BPMN (n = 34)	1.69	1.08	1.89	1.18
Transfer ability scores (acceptable model-based answers)	EPC (n = 34)	0.50	0.75	0.32	0.64
	BPMN (n = 34)	0.26	0.61	0.20	0.47

We note from Table 3 that the transfer ability test scores (acceptable inferential answers) were higher for the BPMN group than the EPC group. Table 4, however, shows that these differences are not significant. In contrast, we note that scores for acceptable model-based answers were higher for the EPC group across both scenarios (mean = 0.50—BPMN: 0.26 for the Goods receipt case, and 0.32—BPMN: 0.20—for the Claims handling case). The data in Table 4 confirms that these score differences are significant, suggesting that the choice of grammar (familiar versus unfamiliar) has a significant effect on model-based transfer abilities. This result suggests that previous knowledge of a modeling grammar assists in understanding the business context as depicted in this model; however, it would appear that such knowledge does not assist in developing deep transfer abilities (as indicated by the non-significant differences in the scores for acceptable inferential answers). In light of these results, we acknowledge that hypothesis H1a is at best partially supported.

Inspection of Table 4 further shows that the use of English as a second language is a significant factor in developing model-based transfer abilities (problem solving capacities on basis of the model presented)—but again, this case does not hold for develop transfer abilities. These results are partially in line with Hypothesis 2a.

We further note from Table 4 that previous experience in EPC modeling shows consistent effects on the inferential transfer ability scores. For the claims handling case, students with higher experience in EPC modeling achieved significantly higher scores for the goods receipt case, and those students with students with higher experience in EPC modeling also performed better in the claims handling case. These results confirm Hypothesis H3a.

In terms of working experience in business process management, the data in Table 4 shows some but inconsistent effects on the inferential transfer ability scores. For the claims handling case, students with previous BPM work experience achieved significantly higher scores for the goods receipt case. Scores in the claims handling were better but not significantly. These results partially support Hypothesis H4a.

Table 4: MANCOVA Results of Transfer Ability Test Scores				
Effect type	Case 1: Goods receipt		Case 2: Claims handling	
	Problem solving (acceptable inferential answers)	Problem solving (acceptable model-based answers)	Problem solving (acceptable inferential answers)	Problem solving (acceptable model-based answers)
Grammar type	F (1,11) = 1.25 (p = 0.28)	**F (1,11) = 2.76 (p = 0.01)**	F (1,11) = 1.46 (p = 0.17)	**F (1,11) = 3.69 (p = 0.00)**
Grammar type * ESL	F (2,11) = 0.88 (p = 0.42)	**F (2,11) = 8.68 (p = 0.00)**	F (2,11) = 0.14 (p = 0.87)	**F (2,11) = 10.74 (p = 0.00)**
Grammar type * EPC experience	**F (2,11) = 3.23 (p = 0.05)**	F (2,11) = 0.31 (p = 0.73)	**F (2,11) = 3.25 (p = 0.05)**	F (2,11) = 1.76 (p = 0.18)
Grammar type * Work experience in BPM	**F (2,11) = 3.75 (p = 0.03)**	F (2,11) = 1.13 (p = 0.33)	F (2,11) = 0.11 (p = 0.89)	F (2,11) = 2.34 (p = 0.11)

Differences in Retention Abilities

We speculated in Hypothesis H1b that surface understanding (in terms of retention abilities) would be higher for the group of users confronted with EPC models that they were familiar with. We speculated in Hypothesis H2b that ESL would have a negative effect on the retention ability test, and in H3b and H4b that participants with higher levels of modeling and BPM experience would score higher.

We again used a MANCOVA with the same independent factors and covariates as above. As dependent variables we used the Cloze test scores for the two model cases considered. Levene's tests were insignificant (F = 0.33, p = 0.57 for case one and F = 0.25, p = 0.62 for case two). Table 5 gives the descriptive results and Table 6 gives the results from the statistical test.

Table 5: Descriptive Results of Retention Ability Test Scores					
Dependent variable	Group	Case 1: Goods receipt		Case 2: Claims handling	
		Means	St. Dev.	Means	St. Dev.
Retention ability scores (correct Cloze test answers)	EPC (n = 34)	9.35	2.70	8.35	4.12
	BPMN (n = 34)	9.26	3.32	8.57	3.92

Table 6: MANCOVA Results of Retention Ability Test Scores		
Effect type	Case 1: Goods receipt	Case 2: Claims handling
	Retention ability scores (correct Cloze test answers)	Retention ability scores (correct Cloze test answers)
Grammar type	F (1,11) = 1.181 (p = 0.321)	F (1,11) = 1.741 (p = 0.088)
Grammar type * ESL	F (2,11) = 1.146 (p = 0.325)	F (2,11) = 3.102 (p = 0.053)
Grammar type * EPC experience	F (2,11) = 0.108 (p = 0.898)	F (2,11) = 1.120 (p = 0.333)
Grammar type * Work experience in BPM	F (2,11) = 1.660 (p = 0.199)	F (2,11) = 0.220 (p = 0.803)

As can be seen from Table 5, Cloze test scores were higher for the EPC group in the (less complex) Goods receipt case but not in the Claims handling case. We observe from Table 6 that neither grammar type nor any of the user characteristics considered display a significant effect on retention ability scores. Therefore, we refute hypotheses H1b, H2b, H3b, and H4b and note that retention ability appears not to be determined by the factors we consider in our study.

Differences in Effort of Understanding

As per our hypotheses H1c, H1d, H2c, H2d, H3c, H3d, H4c and H4d we speculated that differences between the participant groups could also exist in the amount of effort required to develop domain understanding from the

process models. Such differences would manifest in differences in the time taken to complete the different tasks. To that end, we ran another MANCOVA, with the same independent factors and covariates as above, and as dependent measures the recorded test completion times for the transfer ability and retention ability tests across both cases.

Levene's tests were insignificant for each dependent measure ($F (1,50) = 0.41$, $p = 0.53$; $F (1,50) = 0.05$, $p = 0.83$; $F (1,50) = 0.61$, $p = 0.44$; $F (1,50) = 1.71$, $p = 0.20$) indicating adequate data distribution. Table 7 shows means and standard deviations reported for the two task completion times across the two cases. Table 8 shows the result from the MANCOVA test. Significant results are highlighted gray.

Table 7: Descriptive Results of Test Completion Times					
Dependent variable	Group	Case 1: Goods receipt		Case 2: Claims handling	
		Means	St. Dev.	Means	St. Dev.
Transfer ability task completion times	EPC (n = 34)	6.66	2.65	4.68	1.98
	BPMN (n = 34)	7.30	3.26	4.29	2.00
Retention ability task completion times	EPC (n = 34)	3.78	1.39	3.34	1.50
	BPMN (n = 34)	3.87	1.31	3.93	1.87

Table 8: MANCOVA Results of Test Completion Times				
Effect type	Case 1: Goods receipt		Case 2: Claims handling	
	Transfer ability task completion times	Retention ability task completion times	Transfer ability task completion times	Retention ability task completion times
Grammar type	$F (1,11) = 0.00$ (p = 0.99)	$F (1,11) = 0.323$ (p = 0.57)	$F (1,11) = 0.57$ (p = 0.45)	$F (1,11) = 0.49$ (p = 0.51)
Grammar type * ESL	$F (2,11) = 1.97$ (p = 0.15)	**$F (2,11) = 4.30$ (p = 0.02**	$F (2,11) = 1.60$ (p = 0.21)	**$F (2,11) = 8.12$ (p = 0.00)**
Grammar type * EPC experience	$F (2,11) = 1.22$ (p = 0.31)	$F (2,11) = 1.75$ (p = 0.18)	$F (2,11) = 0.37$ (p = 0.69)	**$F (2,11) = 3.16$ (p = 0.05)**
Grammar type * Work experience in BPM	$F (2,11) = 0.61$ (p = 0.55)	**$F (2,11) = 6.80$ (p = 0.00)**	$F (2,11) = 0.26$ (p = 0.77)	**$F (2,11) = 8.47$ (p = 0.00)**

Perusal of Table 7 shows that the EPC group performed consistently faster than the BPMN group in the Cloze test, while time taken for the model comprehension task and the problem solving task varied between the two groups across the two cases. Notably, time taken to complete the problem solving tasks was shorter across both treatment groups in the Claims handling case, suggesting a potential learning effect across all participants during the conduct of the experiment.

Table 8 displays important results. The data shows that the use of a familiar or unfamiliar grammar per se has no significant impact on the effort of understanding, however, the use of a familiar or unfamiliar grammar is an important consideration for different types of users. Specifically, Table 8 shows that the use of English as a second language is an important determinant of the effort required to develop retention abilities (the interaction effect was significant for both model cases). Similarly, consistent significant interaction effects were found to stem from prior BPM working experience. The data in Table 8 further indicates that for the more complex second case, previous modeling experience is an important predictor.

Last, we note from Table 8 that transfer ability task completion times (as measures for deep understanding efforts) do not appear to be significantly influenced by any of the factors considered. In light of these results, we refute hypotheses H1c, H2c, H3c, and H4c while tentatively accepting hypotheses H2d and H4d. Hypothesis H3d only received partial support from the data.

Manipulation Checks

To eliminate potential bias stemming from non-equivalency between the treatment groups, we conducted several manipulation checks to assess differences between the groups of participants across treatments.

First, following the guidelines by Burton-Jones et al. [2009] we examined whether our treatments (the EPC and BPMN models) were approximately informationally equivalent. We used three measures. First, we consider scores from a model comprehension test, following Gemino and Wand [2005]. Second, we record model comprehension task completion times. Third, we consider the perceived ease of understanding the models given, as a measure for effort of understanding, similar to Burton-Jones and Meso [2008]. Table 9 gives descriptive statistics about these manipulation check variables used as well results from two-tailed independent samples t-tests.

Table 9 shows that the EPC group achieved slightly higher comprehension scores than the BPMN group (mean scores for the EPC group: 4.26 and 4.35; mean scores for the BPMN group: 3.77 and 4.20). However, independent samples t-tests showed these differences to be statistically non-significant. Hence, we conclude that the models used are roughly comparable.

We conducted similar manipulation checks using the other control variables (gender, process modeling experience in months, self-perceived grammar familiarity). Independent samples t-tests showed no significant differences in model comprehension scores or comprehension task completion times, indicating that the participants were effectively randomized across treatments.

Table 9: Descriptive Results of Manipulation Check Scores							
Manipulation check variable	Group	Case 1: Goods receipt			Case 2: Claims handling		
		Means	St. Dev.	t (Sig.)	Means	St. Dev.	t (Sig.)
Model comprehension scores (correct answers)	EPC (n = 34)	4.26	1.05	1.78 (0.08)	4.35	1.76	0.36 (0.72)
	BPMN (n = 34)	3.77	1.24		4.20	1.75	
Model comprehension task completion times	EPC (n = 34)	4.06	1.41	1.21 (0.23)	3.19	1.18	−0.39 (0.70)
	BPMN (n = 34)	3.68	1.17		3.33	1.78	
Ease of understanding (1 = strongly disagree, 7 = strongly agree)	EPC (n = 34)	4.72	0.64	0.44 (0.66)	4.65	0.65	−0.87 (0.39)
	BPMN (n = 34)	4.33	0.79		4.18	0.61	

VI. DISCUSSION

Our data analysis concerned the examination of the impact of content presentation form and user characteristics on the development of surface and deep understanding, and the effort of understanding.

Our results suggest that content presentation format (in the form of familiar versus unfamiliar grammar) is a non-significant factor in developing domain understanding. Admittedly, we found some differences yet these are negligible in their significance. Most notably, our results disconfirm our initial expectation that process modeling practitioners develop a better understanding of business domains when using familiar forms of content presentations (viz., process modeling grammars). Indeed, our tests show that this is not the case. Accordingly, these results imply that process modelers with training in a given process modeling grammar perform reasonably well in understanding process models depicted with another, unfamiliar grammar.

Still, these results should be interpreted in light of the interaction effects with user characteristics that we uncovered. For instance, we found that business process management work experience is an important factor in enabling novice developers to understand domain semantics from a process model. Increased experience in applying process management principles to real-life work situations appears to provide a general understanding of the underlying process-oriented paradigm, which facilitates easier learning of different process model representation formats, viz., different modeling grammars. Specifically, our results suggest that BPM work experience is especially of benefit to enable deep understanding, viz., to developing transfer ability skills in applying process model material for problem-solving tasks. Our results suggest that these effects are due to a decreased cognitive load of the experienced modelers. In other words, the gathered experience in using BPM principles aids in decreasing the extraneous load caused by the usage of new material (such as an unknown type of content presentation through a different grammar).

We also found effects of the use of ESL on developing an understanding of process models. More precisely, we found notable differences between native and non-native speakers especially in terms of effort required to develop retention ability, as well as in the ability to reason about a domain on the basis of a given model (as indicated by the

model-based problem solving scores). We speculate based on the results that the textual semantics associated with process modeling can be difficult to understand for individuals with less familiarity with the language used to annotate the models. Similar to the findings by Masri et al. [2008], our results suggest that working with a foreign language denotes an additional source of intrinsic cognitive load, thereby increasing the negative effect of cognitive load on the development of understanding. The results further suggest that the increased cognitive load due to ESL can in some cases even overcompensate decreased cognitive load stemming from the use of familiar content presentation formats (viz., the familiar grammar).

Overall, the uncovering of significant effects of ESL on process model understanding underlines the importance of an often overlooked aspect of process modeling practice—the textual annotation and precise specification of business process domains [Mendling et al., 2010b]. Also, the results present another interesting finding when contrasting the significant impact of ESL with the insignificant impact of BPMN versus EPC: understanding appears to be more dependent on the choice of natural languages than on the choice of artificial, conceptual languages or grammars.

VII. IMPLICATIONS

For Practice

Our research results have implications primarily with respect to educational aspects. We have shown that EPC users can understand BPMN diagrams reasonably well even though they were never exposed to this modeling grammar before. With respect to university curricula, these findings imply that it is neither of much use to include several process modeling grammars into a single course, nor is it of much use to impose an obligation on students to learn several process modeling grammars in several courses. In addition, our findings suggest that process modeling knowledge acquired by students does not simply outdate with a change of prevailing or more common modeling grammars.

Another implication for practice is the insight that a new process modeling grammar does not pose an economic threat to an organization if the majority of BPM actors within this organization are users of a different process modeling grammar, and even more so if the users are experienced (with any type of grammar). It would appear that there is no immediate need for organizations to embark on extensive training courses every time the process modeling grammar in use has to be changed. Instead, our findings suggest that a set of developers equipped with adequate skills in one process modeling grammar will be fit to understand other process models too. Large investments undertaken by organizations to model their business processes can hence be capitalized at later stages even if the used modeling grammar becomes outdated and is being replaced.

For the provider side our results suggest that carefully managed changes to process modeling grammar are not unlikely to be accepted by a customer base. Such changes may always be necessary in certain situations and should be seen as an opportunity rather than a problem. For instance, providers may find the need to enhance the expressive power of a process modeling grammar to be better equipped for future and advanced process modeling needs (e.g., advanced workflow execution, support for Web service specification, etc.). The resulting differences in expressiveness and complexity of the grammar appears to be well-absorbed by the existing user communities.

For Research

We also consider implications for future research on basis of the results obtained. Our results confirm the importance of user characteristics to the process of developing domain understanding from a process model. Our investigation of the effects of a number of user characteristics on model understanding show that modeling experience, BPM work experience, and the use of English as a second language lead to some notable differences in understanding, over and above the impact of the content presentation format. We believe this leads to an interesting avenue for future research that may examine the interactions between model and user characteristics in more detail. For instance, a future attempt at explaining the differences in understanding different types of process models may consider cognitive fit theory [Vessey and Galletta, 1991]. This theory suggests that apart from the representation of a content (or problem), also the nature of the task and the set of skills by the task solver should be examined. A proposition based on the theory of cognitive fit would be that it is the type of process modeling task (e.g., system specification versus process simulation versus process reengineering) that influences the way we obtain domain understanding. In the present study, we used an identical set of tasks for which process modeling was conducted and found that there were no significant differences in the outcomes. It is possible that we would have obtained a different picture if the process modeling tasks were different.

Another avenue for future research can be found when considering our research framework. we referred to the cognitive theory of multimedia learning, which suggests three elements involved in the process: content, content

presentation, and user characteristics [Mayer, 2001]. We have focused the elements content presentation and a preliminary set of user characteristics in our study, while controlling for content characteristics. The next logical step would now be to study different types of content as well as other types of user characteristics. For instance, differences between users in terms of their comprehension skills [Gernsbacher et al., 1990], personality traits [Goldberg, 1990], meta-cognitive abilities [Wang et al., 2006] or previous domain knowledge [Khatri et al., 2006] could manifest in differences in learning how to understanding process models of business domains. Future research could investigate these aspects in more detail.

Limitations

Our study results are conditioned by several limitations. We considered postgraduate students as proxies for novice developers. Therefore, the external validity of our results is restricted, at best, to novice developers in organizations and may not generalize to highly skilled or highly experienced process practitioners.

In terms of construct validity, we operationalized each factor in our study in limited ways. For instance, while we encouraged participants to delineate several possible answers to each process problem in the transfer ability test, in our result coding, we coded only the suitability of answers but not the sheer number of acceptable answers. Coding the number of suitable answers could have informed an opinion how well participants were able to engage in creative problem solving [Martinsen, 1993] on basis of the models presented. However, we did not do so. Thus, our result interpretations should be considered within the boundaries of the treatments, measurement methods, and tasks that we used. Also, we considered only one application task—reasoning about an as-is process. Other task scenarios (e.g., developing improved to-be processes) could have yielded different results, especially in regard to the transfer ability scores recorded.

VIII. CONCLUSIONS

Our research empirically addresses a fundamental aspect of process modeling, namely the development of process model understanding. We operationalized and measured three aspects of understanding, viz., surface understanding in terms of retention abilities, deep understanding in terms of transfer abilities, and effort of understanding. We considered two elements involved in the understanding development process as suggested by Mayer [2001], that is, content presentation and user characteristics. We found that content presentation, viz., different grammars used for the creation of process models, has little influence on developing domain understanding, while some user characteristics do. Specifically, we showed that previous experience with a modeling grammar, previous work experience, and the use of English as a second language are significant factors in developing different levels of understanding, and—most notably—in the effort required to develop understanding (in terms of retention and transfer abilities).

We believe that our approach to conceptualizing understanding as well as the interesting results obtained provide an important contribution to the present body of knowledge and also guide future research in this area.

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APPENDIX EXPERIMENTAL MATERIAL USED FOR GOODS DELIVERY CASE

Case Description

A truck driver registers at the goods receiving department with a delivery note. In his case, it is a delivery related to a purchase order. In case of deliveries without a purchase order, a booking clerk who has the authority to decide whether the delivery is to be accepted has to be contacted. When the decision has been made, the booking clerk notifies the goods reception officer. Following the assignment of a delivery ramp to the truck driver, the goods are inspected. Since the goods inspection proceeds without complaints, the goods are placed into stock. In case of inspection complaints, the goods would have been rejected.

Pre-test and Post-test Scales

1) Familiarity with the EPC grammar (7-point scale from "Strongly disagree" to "Strongly agree")
   a. Overall, I am very familiar with EPCs.
   b. I feel very confident in understanding process models created with EPCs.
   c. I feel very competent in using EPCs for process modeling.

2) Perceived Ease of Understanding (7-point scale from "Strongly disagree" to "Strongly agree")
   a. It was easy for me to understand the EPC model that was given to me.
   b. Overall, I believe that EPC is easy to use for process modeling.
   c. Understanding the EPC model that was given to me was often frustrating.
   d. Learning how to read the EPC model that was given to me was easy for me.

Comprehension Questions

#	Question	Correct Answer
1	Are deliveries without purchase order automatically rejected?	N
2	Can the goods quality be inspected before a delivery ramp is determined?	N
3	Is the booking clerk responsible for acceptance decisions of goods without purchase orders?	Y
4	Can goods be rejected for multiple reasons?	U
5	Can goods be accepted that arrive without a delivery note?	U
6	Can goods be rejected after they have been assigned a delivery ramp?	N
7	Can goods be placed into multiple warehouses?	U
8	Does the booking clerk notify the goods receipt officer via a message?	Y

* Key: Y = Yes; N = No; U = Unknown (cannot be answered from the model)

Problem Solving Questions

1) A set of video recorders arrives at the goods receipt department. The corresponding purchase order is quickly identified. However, it is noticed that the original purchase order requested 200 video recorders but 400 video recorders are delivered. What are the options to handle this situation?
   a. Example acceptable answer: Accept all four hundred recorders and amend purchase order.
   b. Example acceptable answer: Identify potential warehouse space and store additional video recorders.
   c. Example acceptable answer: Correspond with goods receipt officer to inquire about need for additional video recorders.

2) A truck arrives at the goods receipt department with a delivery to which no corresponding purchase order can be identified. The goods receipt officer sends a message to the booking clerk. However, as time passes, no answer from the booking clerk is received and the truck driver is getting anxious. What are the options for the goods receipt officer to resolve this dilemma?

3) A delivery is received as planned. A delivery ramp is determined and the delivered goods all pass the quality inspection. However, during unloading it is recognized that there is insufficient storage space in the warehouse to store all the goods. In fact, 40 percent of the delivery does not fit into the goods receipt warehouse. What are the options to handle this situation?

Cloze Test

A truck driver registers at the goods receiving department with a _____ In his case, it is a delivery related to a _____. In case of deliveries _____ purchase order, a booking clerk has to be contacted that has the authority to _____ whether the delivery is to be accepted. When the decision has been made, the booking clerk _____ the _____ _____ officer. Following the assignment of a _____ _____ to the truck driver, the goods

are _____. Since the goods inspection proceeds without complaints, the goods are _____ into stock. In case of inspection complaints, the goods would have been _____.
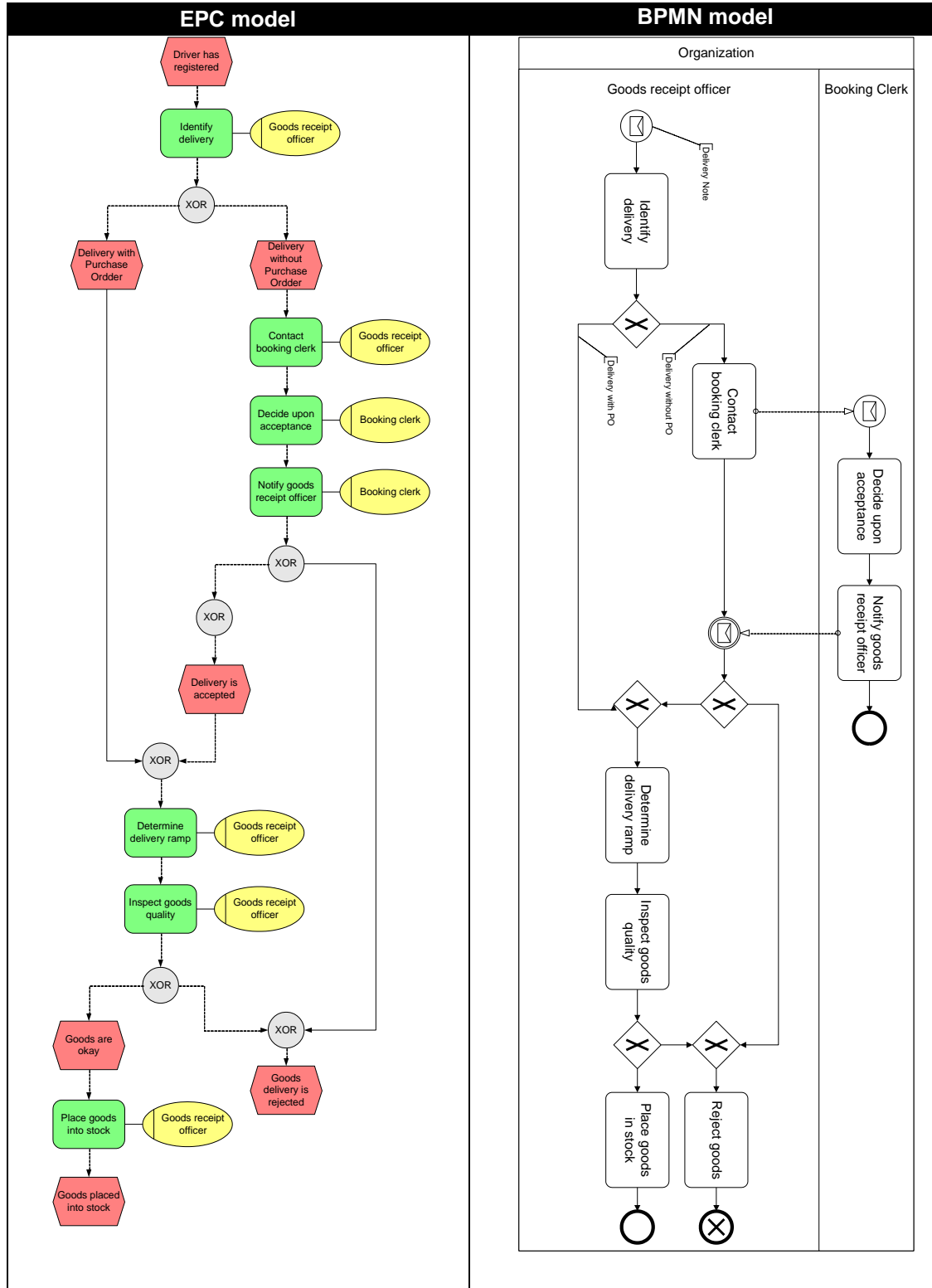
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