An Experiment to Analyze the Use of Process Modeling Guidelines to Create High-Quality Process Models

Diego Torales Avila[1], Raphael Piegas Cigana[1], Marcelo Fantinato[2], Hajo A. Reijers[3], Jan Mendling[4], and Lucineia Heloisa Thom[1](✉)

[1] Institute of Informatics, Postgraduate Program in Computing, Federal University of Rio Grande do Sul, Porto Alegre, Brazil
{dtavila,rpcigana,lucineia}@inf.ufrgs.br

[2] School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, Brazil
m.fantinato@usp.br

[3] Department of Information and Computing Sciences, Universiteit Utrecht, Utrecht, The Netherlands
h.a.reijers@uu.nl

[4] Vienna University of Economics and Business, Vienna, Austria
jan.mendling@wu.ac.at

Abstract. Process modeling guidelines are an essential tool to help process modelers to create models that are correct and easy to understand. Many guidelines have been proposed in the literature, but there is little empirical evidence to which extent guidelines are effectively used. This paper addresses this research gap by presenting the results of a semi-controlled experiment conducted on two occasions with 21 students from a Business Process Management course. Two successive process modeling tasks were compared, one before and one after the subjects were presented to a set of 20 guidelines, which were collected through a systematic literature review. From the results obtained with the experiment, it was observed that the subjects would be more receptive to the guidelines if they were easier to understand and use.

Keywords: Process modeling · Process modeling guidelines · BPM · BPMN · Experiment

1 Introduction

Business process modeling is a difficult [7] but important task, in which a process analyst studies the business processes of an organization to create a representation – graphical, usually – of its activities, events and control flow logic [4]. The result is a process model, which may be used as a tool for learning, improvement and communication of the business process. While it is important that process models have high quality [13], they often have modeling issues, such as control

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flow errors, badly designed structures and layouts, or incorrect labeling [6], which may significantly impair their understandability.

A frequent cause of these issues is the inexperience of process modelers [9], which can be lightened by the use of process modeling guidelines [6]. Guidelines are simple rules that help in creating more understandable process models and with fewer errors [7]. For example, a common modeling guideline is to use fewer modeling elements. Many guidelines are a result of experimental research that sought to understand what characteristics of process models influence their quality. Despite this, it is still uncertain whether process modelers, especially beginners learning to model, can successfully use guidelines to create better process models.

In this context, this paper reports an experiment in which the use of process modeling guidelines is analyzed for a process modeling task. We asked students of a process modeling course to create two process models, with only the second modeling task being supported by a set of modeling guidelines we collected from the literature. The data collected through this experiment was evaluated via statistical analysis. This experiment was executed twice with two sets of students and both datasets were merged for analysis and reporting. We present in this paper the protocol and the instruments designed for this experiment. We also exhibit the statistical analysis and the discussion of the results.

This paper is organized as follows: Sect. 2 provides background on process modeling guidelines and discusses other work related to this paper. Section 3 defines the protocol of the experiment, its hypotheses, design and instruments. Section 4 presents the results of the experiment, the test of the hypotheses and a discussion of the results. Section 5 concludes this paper with a summary and an outlook for future work.

2 Background

This section presents the fundamental background of our work. First, we present the set of process modeling guidelines that was used during our experiment. Second, we describe the related work on modeling guidelines.

2.1 Process Modeling Guidelines

Prior to our experiment, we have conducted a systematic literature review [1] in search of insights on important characteristics of high-quality process models that were interpreted as or transformed into a set of 45 modeling guidelines. These studies analyzed by the review did not share a common modeling notation among themselves, so all the extracted guidelines were adapted to the Business Process Model and Notation (BPMN) [11], which has been rising in popularity in recent years, as perceived throughout the review.

One characteristic discovered during this review was that not all guidelines were equally valuable or useful. Some of the guidelines we found were not studied in an empirical research to determine if they can improve the understandability of process models without changing their underlying behavior. Thus, these guidelines may be detrimental to the process modeling task, possibly even reducing the quality of the resulting process model. In our experiment, for example, they may have made it considerably longer and more difficult for its subjects. Therefore, we found it necessary to remove these guidelines.

Table 1 shows the set of guidelines we chose to use in our experiment. These guidelines were selected through a manual analysis, removing those that are possibly detrimental to the modeling task. We also removed those that were too similar to the guideline "Use as few elements as possible", since they could be considered redundant. The guidelines are arranged in four categories: *size*, which related to the size of the process model, *topology*, which contains guidelines on how model elements combine with each other, *layout*, which consists of conventions on how the process model should be visually presented, and *labeling*, which has instructions on how to label model elements.

2.2 Related Work

Defining what is process model quality has been a long-standing issue to which theoretical frameworks such as SEQUAL, SIQ and the Guidelines of Modeling (GoM) [2,5,13] were created. While insights provided by these frameworks are invaluable, they often define quality categories overly abstractly to be applied by novice modelers. In addition, the frameworks do not provide a straightforward method for their implementation in a process modeling project [7].

Creating more concrete and straightforward guidelines to be used in process modeling may solve this problem. One well-known work on modeling guidelines is the "Seven Process Modeling Guidelines (7PMG)" proposed by Mendling *et al.* [7]. It is notable for synthesizing a set of guidelines built upon empirical insights and contributing a ranking of them based on the opinions of expert analysts. This ranking solves the issue of when modelers have the opportunity to apply multiple guidelines that guide them to conflicting solutions.

Another important work is from Moreno-Montes de Oca *et al.* [10], in which a set of 30 modeling guidelines was presented to students that were asked to evaluate each one individually through its perceived ease of use, perceived usefulness and behavioral intention. The results were then compared against each other to find the highest scoring guidelines for these variables and their correlations.

Despite these studies, we found none that analyzes one of the main goals of modeling guidelines, which is to guide inexperienced process modelers to create more understandable process models. Thus, in our work, we use the set of modeling guidelines from Table 1 to evaluate whether this goal can be completed and what are the main challenges faced by inexperienced process modelers when using modeling guidelines.

Table 1. Process modeling guidelines used in this experiment (from literature review)

ID	Guideline	Category
S-1	Use fewer than 37 modeling elements	Size
S-2	Avoid using inclusive (OR) gateways	Size
S-3	Do not use implicit gateways	Size
S-4	Minimize the degree of all gateways	Size
T-1	Model as structured as possible	Topology
T-2	Do not create cycles with multiple exit points	Topology
T-3	Decompose models that are too large	Topology
T-4	Decompose model fragments that occur multiple times or that benefit from being grouped together or hidden	Topology
T-5	Do not overly decompose the process model	Topology
Ly-1	Minimize the drawing area of the model (preferably within a page)	Layout
Ly-2	Make the process flow from left to right	Layout
Ly-3	Minimize the number of bends in sequence flows	Layout
Ly-4	Minimize the crossing of sequence flows	Layout
Ly-5	Make use of symmetry between elements	Layout
Ly-6	Avoid overlapping elements	Layout
Ly-7	Keep model elements related to one another close to each other	Layout
Lb-1	Label everything necessary	Labeling
Lb-2	Use a consistent labeling style, such as: verb-object style for activity labels; object-particle style for event labels; and object-particle question style for gateway labels	Labeling
Lb-3	Avoid labels that are vague or ambiguous	Labeling
Lb-4	Use short labels	Labeling

3 Experiment Protocol

This section presents the research method applied to conduct this study, which is through an experiment. It displays the protocol used to conduct our experiment, which includes the definition of hypotheses and variables, the design of the experiment, the selection of subjects and instruments, and how the data collected was validated.

3.1 Problem Definition and Hypotheses

The influence that modeling guidelines have on process modeling is still an open issue. Since they are an additional concern to the task of modeling, they presumably affect cognitive load [14]. As such, they may increase extraneous cognitive load and block cognitive resources, making process modeling more difficult by requiring modelers to monitor not only the process being modeled but also whether the guidelines are being met. Consequently, if modelers believe they have more difficult modeling while using the guidelines, they may feel discouraged from using them again. Another possible effect would be modelers feeling the need to rely on some method or tool to support the use of guidelines. On the other hand, if the guidelines are formulated as clear instructions on how to model correctly, the increased cognitive load might be a germane cognitive load that helps the modeler in their task.

It is also unclear how effective a modeler can be when using modeling guidelines after being introduced to them. Pragmatically, modeling guidelines should be straightforward and well-founded rules that show how to create a better quality process model [7]. However, some guidelines found in literature have no explicit instructions as to when they can be applied; for example, when to use subprocesses. This imprecision can cause difficulties for modelers. Finally, modelers can perceive their process models with a higher level of understandability after using modeling guidelines, even though they have not been used correctly or other modeling issues still remain.

Considering these issues, we formulated three hypotheses in this paper: [H_1] guidelines increase cognitive load, which leads process modelers to a perception of higher degree of difficulty when modeling with the support of process modeling guidelines than without them; [H_2] process models created with the support of process modeling guidelines have *fewer modeling issues* than those without them; and [H_3] process modelers believe their process models have *higher level of understandability* when using process modeling guidelines than when not using them.

Besides these hypotheses, we searched for how receptive the modelers are to process modeling guidelines. They were specifically asked about how easy to use and how useful the guidelines are and if they intend to continue using them.

3.2 Experiment Variables

Based on the hypotheses, we defined three dependent variables: for H_1, we measured the *perceived level of difficulty* the modelers had during process modeling through a 5-point Likert scale, ranging from "very easy to model" to "very difficult to model"; for H_1, we measured the *perceived level of difficulty* the modelers had during process modeling through a 5-point Likert scale, ranging from "very easy to model" to "very difficult to model"; for H_3, we measured the *perceived level of understandability* of the process models, from the point of view of their modelers. This variable was also measured through a 5-point Likert scale, ranging from "very easy to understand" and "very difficult to understand".

Three additional dependent variables were defined for the modelers' receptivity to the modeling guidelines: perceived ease of use, perceived usefulness and future intended use. For each one, the subjects' opinions were measured using a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree".

Personal factors, such as experience in modeling, are also a possible influence on the understanding and performance of subjects interacting with process models [3]. Therefore, we measured the subjects' experience through three independent variables: process modeling, BPMN and other process modeling notations. Each of these variables was measured using a 5-point Likert scale, ranging from "not experienced" to "very experienced" and their values were averaged to define the subjects' overall modeling expertise. Finally, the subjects were also asked whether they knew some set of process modeling guidelines, as such knowledge could also be an influence.

3.3 Experiment Design and Subjects

The goal of the experiment was to compare the performance of subjects in two process modeling tasks based on having or not the support of modeling guidelines. We gave the subjects textual descriptions of two processes, one for each step of the experiment. In the first step, the subjects were asked to model a first process. In the second step, they were presented to the list of modeling guidelines and encouraged to use them when modeling a second process. Since the order of which process would be modeled first could influence the results, the subjects were randomly separated into two groups, with the order of the processes alternated. Figure 1 shows the design of the experiment.

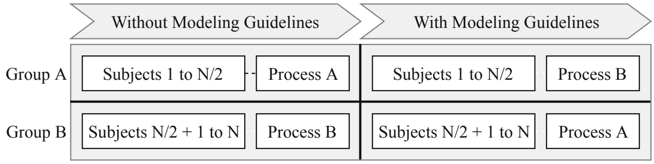

Fig. 1. The experiment design.

The subjects were students enrolled in an introductory course of business process management at a Brazilian public university. We selected students because, due to their inexperience, they might be more motivated to learn how to model processes better, which is a goal of modeling guidelines. The subjects were assumed to be familiar with the basics of process modeling and BPMN. An overview of the experiment was presented to the subjects, with general goals, procedures and time limits for each step. They were encouraged to create process models with quality in mind.

The experiment was executed twice. First, 13 subjects participated (divided into two groups). Then, the experiment was replicated with eight other subjects. Each execution was performed in a single laboratory with all subjects at the same time. The subjects had a limited time to perform each step of the experiment, whose total took an average of 80 min to complete. In addition, any questions the subjects might have about the procedure could be answered by the authors who were controlling the experiment.

3.4 Experiment Instrumentation

Four instruments were used during the experiment. The first one was the list of process modeling guidelines presented in Table 1, along with a small description for each guideline detailing how to apply it. The second instrument was the *Bizagi BPM modeler*[1], a modeling tool that is used during the university's Business Process Management course to learn process modeling. The third instrument was an on-line questionnaire that collected data measuring our independent and dependent variables. It also had open-ended questions where the students could provide reasoning for their answers and their opinions about the modeling guidelines.

The last instrument was the processes that would be modeled during the experiment. They came from a collection of real-world process models from a Brazilian public university. We sought in this collection two process models with complexities similar to each other and that could provide opportunities for the use of the modeling guidelines. The selected process models are medium-sized (i.e., over 20 elements), with at least one loop, a potential sub-process and multiple exclusive (XOR) gateways. We also ensured that the subjects had no in-depth prior knowledge of the selected processes. Finally, the selected process models were manually transcribed into a textual description.

3.5 Data Validation

All 21 subjects completed the experiment, and data collection through the questionnaire was successful. Although 42 process models were collected, eight models were excluded from the analysis of the hypothesis H2 (four from the first part of the experiment and four from the second part) because they contained serious syntax errors. These errors occurred because the subjects were unable to finalize the process modeling in the available time.

4 Data Analysis and Interpretation

This section presents the results of the experiment and its analysis, including some descriptive statistics, the hypothesis testing, and finally the discussion of the results.

4.1 Descriptive Statistics

All subjects reported knowledge of the 7PMG guidelines [7], which was expected by us, as they were introduced in the BPM course from which the subjects were recruited. The overall experience of both groups of subjects, calculated by averaging the three modeling experience variables, was similar. *Group A* had an average experience of 2.88 and standard deviation of 0.5, while *group B* had an

[1] www.bizagi.com/en/products/bpm-suite/modeler.

average of 2.97 and standard deviation of 0.67. We have not found any significant outlier, thus we can assume that these groups are homogeneous.

Figure 2 shows the distribution of the responses to the variables related to the hypotheses H_1 and H_3, respectively. After introducing the guidelines, there was a slight worsening in the *perceived level of difficulty*, but there was also an improvement in the *perceived level of understandability*.

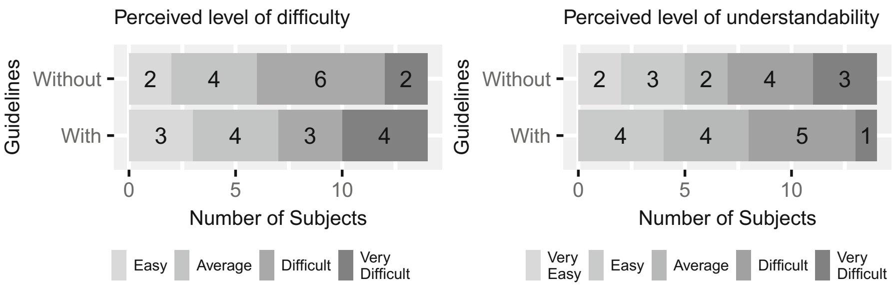

Fig. 2. Data collected for the *perceived level of difficulty* and *understandability*.

Regarding the hypothesis H_2, the subjects had an average of 7.35 *modeling issues* when modeling without guidelines and 7.94 when modeling with them. The standard deviation was 2.74 and 2.73, respectively. The increase in the average when modeling with guidelines goes against our expectations as we had assumed that the guidelines would help process modelers avoid modeling issues.

Figure 3 shows the responses regarding the receptiveness to the modeling guidelines. Although all subjects recognize the usefulness of the guidelines and almost all intend to use them again, some of them do not consider them easy to use. Through the open questions, some subjects addressed their difficulty in understanding how to apply some guidelines. One of the subjects argued that their questions could be clarified with practice and study.

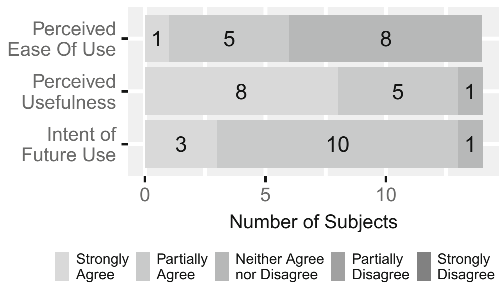

Fig. 3. Receptiveness to the modeling guidelines.

4.2 Hypothesis Testing

To address our three hypotheses, we tested if there was statistical difference between the results of each dependent variable for each step of the experiment, i.e., the two modeling tasks. To select the type of hypothesis test to apply, we first used the Shapiro-Wilk test, a powerful normality test [12], to check if the data collected was normally distributed. Then, the appropriate parametric or non-parametric test was chosen, depending on the type of the dependent variable.

For H_1 and H_2, the Shapiro-Wilk test confirmed that data for the *perceived level of difficulty* and *modeling issues found* are normally distributed. Thus, we applied a *one-sided paired t-test* [8], which is commonly used when the sample data comes from experiments with a paired design, such as this one. For H_3, the variable *perceived level of understandability* was not found to be normally distributed. Therefore, we applied a *one-sided Wilcoxon signed-rank test* [15]. For all three hypothesis, the tests showed that there is no significant difference between the two steps of the experiment. The resulting p-values were 0.6974, 0.2106, and 0.7288 (for H_1, H_2 and H_3 respectively), which are not significant at a significance level of 0.05.

4.3 Discussion

While all 21 subjects fully performed the experiment, it was not possible to find statistical support for the hypotheses pursued. The sample size is possibly a limiting factor for the statistical power of the tests carried out. Nevertheless, the experiment shows that it is possible to analyze the effect that process modeling guidelines have on the process modeling task through the protocol established to investigate our hypotheses.

More detailed information was identified in the responses to the questionnaire's open-ended questions. We realized through them how difficult it was for the subjects to effectively deal with and use the modeling guidelines in a quality-focused process modeling task. Many subjects reported they had to struggle to model the processes because many modeling elements were required. They blamed this over-effort mainly on an over-complexity of the processes. Further, one subject reported that the Bizagi tool impaired their organizational ability when working with a large number of modeling elements.

Subjects did not blame the difficulty to model processes on the use of (or the lack of) modeling guidelines. Instead, they reported that the processes *per se* were difficult to model. This also holds true for the quality of the process models they created. Only when asked directly on the modeling guidelines, some of them reported difficulty also in understanding and using the modeling guidelines.

This analysis is reflected through the data collected to assess the subjects' receptiveness to the guidelines, in which usability and intent of future use received good evaluations while ease of use received moderate ones. These results may mean that modeling guidelines require further refinement to make them easier to understand and use. One option would be to implement modeling guidelines directly in a modeling tool to support the process modelers during their work.

5 Conclusion

This paper reports on an experiment conducted to analyze the effects of using process modeling guidelines. These effects were measured based on the level of difficulty to model and the level of understandability of the resulting process models, both from the perspective of the modeler, as well as the effect on the number of modeling issues in the resulting process models. Two process modeling tasks were compared, one with and one without the support of modeling guidelines. Based on the results, it was not possible to provide significant evidence that the use of process modeling guidelines influences the measured variables. The best likely reason is the small sample size that may have affected the statistical conclusion validity.

In future research, this experiment can be improved to address the identified issues, focusing especially on strengthening the power of the statistical tests. Other approaches to applying the modeling guidelines should also be investigated, such as using a modeling tool to automatically verify whether a process model meets them. Finally, to address the issues modelers had related to ease of use, it seems valuable to analyze which modeling guidelines could be simplified or would demand further training.

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