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An Empirical Analysis of the Influence of Application Experience on Working Methods of Process Modelers

A. Nielen, S. Mütze-Niewöhner, C. M. Schlick

***Abstract*—**In view of growing competition in the service sector, services are as much in need of modeling, analysis and improvement as business or working processes. Graphical process models are important means to capture process-related know-how for an effective management of the service process. In this contribution, a human performance analysis of process model development paying special attention to model development time and the working method was conducted. It was found that modelers with higher application experience need significantly less time for mental activities than modelers with lower application experience, spend more time on labeling graphical elements, and achieved higher process model quality in terms of activity label quality.

***Keywords*—**Model quality, predetermined motion time system, process modeling, working method.

I. INTRODUCTION

THE evolutionary approach to Business Process Management (BPM) relies on a sound and continuous improvement of processes in small steps and has gained wide acceptance in corporate practice [1], [2]. Process models are of utmost importance to BPM [3] since they capture important corporate know-how, facilite continuous improvement efforts, and provide a basis for the certification according to a commonly-accepted quality standard. Further benefits of process modeling refer to information system specification [4], [5], knowledge management implementation and maintenance [6], organizational transparency [7], and workflow design assistance [8].

Alongside with the growing dominance of the service sector in Western economies, the provision of a service should also be viewed as a process which can be broken down into individual or functional service activities. From this perspective, services are as much in need of modeling, analysis and improvement as other types of processes, e.g., business processes or work processes.

II. BACKGROUND

A. Process Model Quality

Capturing and modeling organizational processes is a timely and valuable, but also complex and error-prone task [9], [10]. The issue of model quality is therefore of major importance to process modeling and has been addressed by many authors from both science and practice for almost twenty years [11], [12], [13], [4]. Just like in quality management literature, the distinction between product and process quality also applies to process modeling [12], [14], [15].

Product quality focuses on characteristics of the process model and represents the traditional approach to quality assurance. A modern TQM-like approach is to focus on process quality. With regard to process modeling, the objective is to integrate quality aspects into the modeling process instead of trying to increase the quality of the process model through reviews and inspections.

Several frameworks and guidelines have been developed to ensure high process model quality, including the Guidelines of Modeling (GoM) [16] the SEQUAL framework [17], the Seven Process Modeling Guidelines (7PMG) [18], and the SiQ-framework [4]. These frameworks provide validated sets of rules and put an emphasis on essential quality parameters for process models. A major drawback of these frameworks is that they are either to abstract for usage in corporate practice or almost exclusively focus on product quality [19].

From the part of the modeling tool vendors, the major focus in order to ensure model quality is on technical support via syntactical verification, mini toolbars for fast modeling and functionalities for model layout optimization [20].

Several authors point out that research in process modeling should investigate other issues than features of modeling languages since there is a plethora of languages [12] and computer-based modeling tools available on the market [19], [21], [22], [23], [24], [25].

Instead, research should provide empirical insights how to use modeling languages in order to have a much bigger impact on process modeling in corporate practice [19]. Reference [26] describes the need for an effective and efficient modeling support in order to evolve from an art of a few specialists to a daily routine for regular staff. Regular staff tends to have a low modeling competence and usually conducts process modeling on an irregular basis [24]. From both a technological and an organizational perspective, there is a need to assist casual modelers to conduct process modeling in a more productive way [26].

B. Empirical Research in Process Modeling

Most of the empirical research conducted so far addresses quality aspects of process models such as understandability or complexity [4], [27], [28], [29], [30], [31] and complexity of modeling languages [32], [33], [34], [35].

In connection to this stream of research several authors point out that both modeling tool vendors and consumers put too much emphasis on the keystrokes of the modeling tool although the capabilities of the modeler are of major importance to modeling success [24], [36].

References [25] and [31] provide empirical evidence that prior experience with a particular modeling language might not be of major importance when using another modeling language.

A. Nielen, S. Mütze-Niewöhner and C.M. Schlick are with the Institute of Industrial Engineering and Ergonomics at RWTH Aachen University, Aachen, Germany (phone: 0241-80-99440; fax: 0241-80-92131; e-mail: {a.nielen; s.muetze; c.schlick}@iaw.rwth-aachen.de).

With regard to the BPMN, only the core elements are used frequently in corporate practice [37], [38]. There is an obvious need for empirical insights on the process of modeling that can be of particular value for casual modelers or novices. From an industrial engineering point of view, research on process modeling lacks sound empirical data on different working methods in process modeling.

C. Atypical application of Predetermined Motion Time Systems (PMTS)

PMTS like Methods-Time Measurement (MTM) [39], Work Factor (WF) [40], or the Maynard Operation Sequence Technique (MOST) [41] are methods primarily used to analyze manual work processes and to design or optimize work systems.

PMTS can also be utilized to obtain hints about possible improvements with regard to an existing working method or to support the identification of the most efficient working method from a selection of alternative working methods [42]. As a result, the underlying work processes can be described for education and instruction purposes [43].

Analyses by means of PMTS can generally take place on different levels of detail. These levels can either be fundamental motions like reach or grasp (MTM-1), a sequence of motions such as get or place (MTM standard data/basic values), or fundamental operations like get and place (MTM-UAS/-MEK).

Within the context of process modeling, the application of PMTS bears the potential to gain insight into the working methods of modelers. Despite the possibility to (re-)design the socio-technical work system under investigation, inefficiencies and pitfalls with regard to the working method become transparent by means of a PMTS application.

Mental activities require some further explanations since they cannot be modeled with most PMTS if they go beyond simple yes or no decisions.

Since the introduction of the WF-standard element mental processes by [44], mental procedures during planning or correction can be captured by PMTS—cognitive processes or creative work are excluded [45].

The application is limited to tasks with transmission of information perception to an immediate action, e.g., checking the process model results in a corrective action or placement of a graphical element.

III. LABORATORY STUDY

With regard to the absence of empirical research with regard to the working methods of modelers with different application experience, this paper addresses the following research question:

Which working methods exist in process modeling, i.e., how do modelers with different levels of application experience actually use a modeling language?

The research question addresses an issue that has rarely been addressed in process modeling research, despite the fact this question is critical for research to have a larger impact on process modeling in corporate practice and teaching concepts.

A. Methods

This section describes the empirical study according to [46].

1) Selection of Subjects

A total of 15 subjects—twelve men and three women aged between 26 and 38 years (31.4 years, SD = 3.29)—participated in the experimental study. All of them were research assistants at a technical university in Germany. The type of sampling is quota sampling since the subjects are chosen from modeling affine disciplines, i.e., industrial engineering, business information systems, and software engineering. Each subject had at least one year professional experience in his respective field from both industrial and research projects. All subjects had the German A-Level and hold an academic degree in their scientific discipline, three hold a doctorate.

The subjects were divided into three groups according to their level of application experience. Group I consisted of six research assistants that stated to have created more than 20 process models so far and to frequently model business processes or work processes. Group II consisted of four research assistants that stated to have created between at least five but less than twenty process models so far and to rarely model business and work processes. The five subjects in group III stated to have created less than five process models.

2) Experimental Design

The experimental design is illustrated in Fig. 1. It shows the independent variables, the experimental design, and the dependent variables.

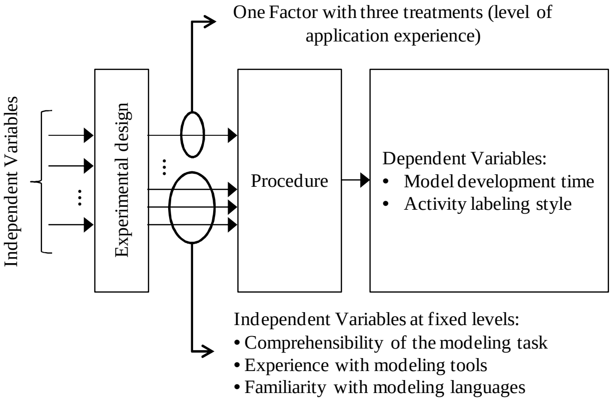

Fig. 1 Illustration of the experiment according to [46]

The design type is one factor with three treatments since three levels of application experience are distinguished.

Since there is only one modeling task in this experiment, randomization is not an important design issue.

The subjects used for this experiment may have different experience with computer-based modeling tools. Some of them have used such tools before, some have not. To minimize this effect, a novel setup was preferred (cf. next section).

Since the three treatments do not have an equal number of subjects, the experimental design is not balanced.

3) Apparatus

The working area was a whiteboard mounted on a height-adjustable table. The subjects could therefore take an ergonomic position for task solving. This novel setup was preferred to a computer-based design in order to exclude the influence of prior experience with modeling tools like ARIS, Microsoft Visio or Eclipse.

Fig. 2 Tangible C3 modeling shapes

The subjects used tangible modeling shapes which represented the C3 basic elements (cf. Fig. 2). This set of elements is quite similar to the ones of other popular control flow oriented process modeling languages like the Business Process Modeling Notation (BPMN) or the Event-Driven Process Chain (EPC) (cf. Fig. 3).

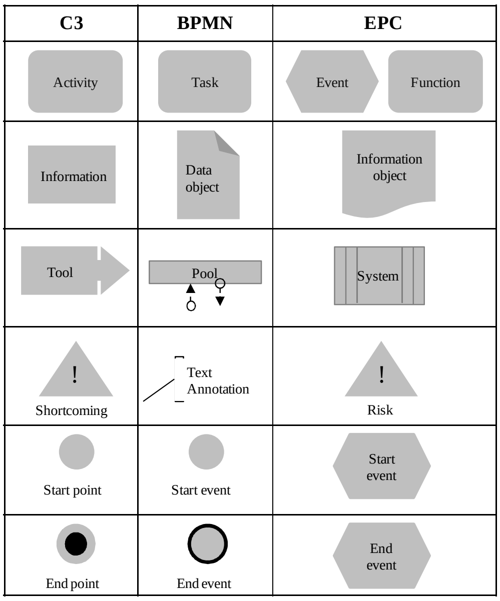

Fig. 3 Graphical elements of C3, BPMN, and EPC

The C3 connectors and routing elements had to be drawn on the whiteboard by means of a board marker. Labeling the C3-shapes as well as writing on the whiteboard also had to be carried out with the board marker.

4) Procedure and instrumentation

Prior to the main experiment, the personal data were collected—this includes age, profession, educational background, and duration of affiliation to a particular scientific discipline. The level of application experience was determined by means of a questionnaire in a pre-test, including questions on the number of created process models, frequency of application of process modeling at work, experience with computer-based modeling tools as well as knowledge and main use of process modeling languages. A brief introduction phase followed in which each subject was introduced into C3 by means of a design template. The template showed a sample process model with brief explanations of the C3 graphical elements. The subjects had to read the explanations and were allowed to ask questions on the C3 elements in order to resolve possible uncertainties. The allotted time for completing the modeling task was not limited. Finally, the subjects had to fill out a questionnaire with items related to quality issues of process models.

Instrumentation for an experiment includes objects, guidelines, and measurement instruments [46]. For the empirical study, instrumentation includes paper-based questionnaires for the pre-test and the post-test, a design template, the tangible C3 modeling shapes provided in a tray, and a board marker. Both procedure and instrumentation are illustrated in Fig. 4. The design template was created in adherence to the 7PMG [18].

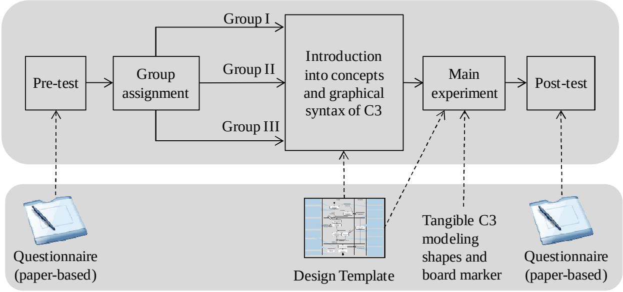

Fig. 4 Procedure (upper box) and instrumentation (lower box)

5) Modeling Task

The main experiment comprised a text-based modeling task dealing with a knowledge-intensive service process—the development of a control unit for the automotive industry. Task size was kept around fifty graphical elements since this is the upper bound for a single process model according to the 7PMG [18]. The text of the modeling task comprised 615 words of which 128 had more than three syllables. During modeling task creation, value was placed on a comprehensive text and that no special knowledge, e.g., domain knowledge, is required to solve the task.

6) Dependent and Independent Variables

In accordance with the experimental design, the design type of the experiment is one factor with three treatments, i.e., the independent variable is the level of application experience in process modeling at three different levels.

The independent variables kept at fixed levels are prior experience with computer-based modeling tools, and unfamiliarity with the modeling language in use [25], [31].

Two types of dependent variables were distinguished. Model development time and working method are process-related variables and activity labeling style is a product-related variable. This distinction picks up the current discussion on process and product quality mentioned in section I.

7) Hypotheses and Statistical Analysis

The level of application experience is likely to affect model development time as well as time for mental activities:

1) Model development time is significantly higher for subjects with low application experience (H1).
2) Time required for mental activities is significantly lower for subjects with higher application experience (H2).

Personal factors such as application experience are likely to affect the subject's working method. Considering this, the following hypothesis was formulated:

3) The working method of a subject with a high application experience is more exact and cadenced than the working method of a subject with a low application experience (H3).

Based on the results of a previous study [47], the application experience is likely to affect the quality of the process model:

4) Subjects with a high level of application experience achieve higher model quality in terms of activity label quality (H4).
5) Proceeding from H4, subjects with higher application experience spend significantly more time on labeling than subjects with lower application experience (H5).

The statistical analysis was conducted with the statistical software package SPSS Version 19.0. A one-way analysis of variance (ANOVA) was calculated to test hypotheses H1, H2, and H5. For multi-level comparison of means the Bonferroni post-hoc test was calculated. A Chi-square test was calculated to test the hypothesis H4. The significance level for each analysis was set at $\alpha=0.05$.

B. Results

The videotapes were analyzed in real-time and classified into a predetermined format of fundamental operations. The level of detail is quite similar to the MTM Universal Analyzing System (UAS) since it refers to fundamental operations in process modeling such as get and place of a graphical element or labeling (cf. Fig. 5).

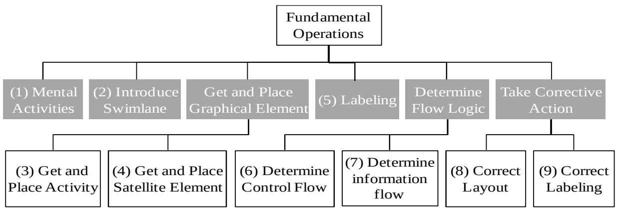

Fig. 5 Fundamental operations considered in the empirical study

The duration of each of the nine fundamental operations given in Fig. 5 was logged by means of a custom-made software program. This program was equipped with nine buttons in order to start the timing and introduce a change of operation at the same time. An additional tenth button was introduced for two major reasons.

First, it allowed for capturing the repeated execution of the nine fundamental operations and to determine the total time for each recorded fundamental operation. Second, time-consuming activities like movements around the working area or search for graphical elements in the tray could be excluded from the analysis. Like in regular PMTS usage, the time consumption for task completion is calculated by adding the total time for each fundamental operation.

1) Model development time

The results of the one-way ANOVA do not show a significant main effect of level of application experience in process modeling on model development time (F(2,14) = 1.396, p = 0.285). The first hypothesis (H1) cannot be accepted.

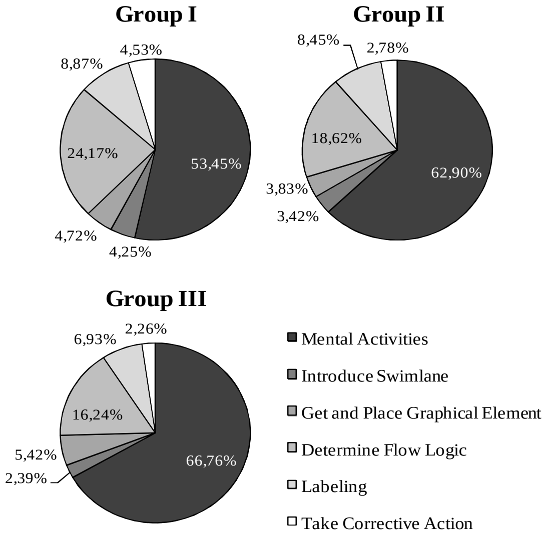

Fig. 6 Average time for each fundamental operation (in percent)

With regard to mental activities, the results of the one-way ANOVA show a significant effect of application experience on time for mental activities (F(2,14) = 4.642, p = 0.032) as well as on time for labeling (F(2,14) = 7.547, p = 0.008). The hypotheses H2 and H5 can therefore be accepted.

Fig. 6 shows the percentage of each fundamental operation in relation to model development time, i.e., the total time for task solving. Concerning the other fundamental operations, the time differences were not statistically significant.

2) Working Method

As a result of the video analysis, two basic working methods were identified. The first working method is given in Fig. 7. It is characterized by a constant change between the elaboration of structure and behavior from the start to model completion. Ten subjects adhered to this working method.

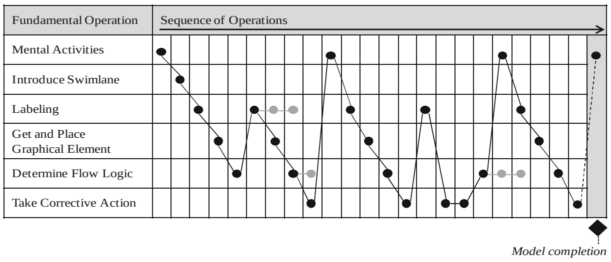

Fig. 7 First identified working method

The second working method (cf. Fig. 8) can be denoted as a more systematic, planned, and cadenced approach to process modeling. It was chosen by three subjects and is characterized by an almost complete definition of the structure of the process, followed by the elaboration of the behavior of the process.

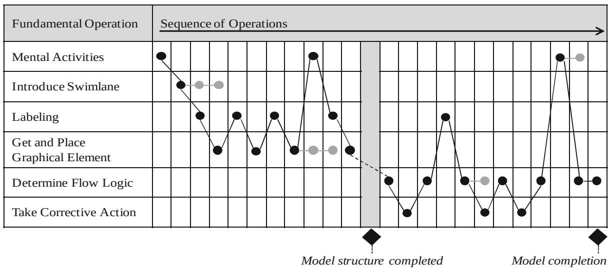

Fig. 8 Second identified working method

Two more subjects divided the process into partial models and elaborated these models one by one according to either the first or the second working method.

H3 can only be accepted with restrictions for two reasons. First, only three subjects chose the second working method (cf. Fig. 8).

Second, only two out of these three subjects had the highest level of application experience in process modeling, but the third was very familiar with the development of software development processes.

3) *Activity Labeling Quality*

Three activity labeling styles were distinguished as shown in Table I.

TABLE I
CONTINGENCY TABLE OF LABELING STYLE FREQUENCIES

Group	Activity labeling style			Total number of modeled activities
	Verb-object	Action-noun	Neither	
Group I	193 (83.19%)	18 (7.76%)	21 (9.05%)	232
Group II	51 (35.17%)	67 (46.21%)	27 (18.62%)	145
Group III	112 (60.87%)	49 (26.63%)	23 (12.5%)	184

The associated statistic ($\chi^2(2) = 95.26$, df=4, $p = 0.000$) shows a statistically significant difference between the three levels of application experience. H4 can therefore be accepted.

C. *Threats to Validity*

The authors affirm that there are some limitations mainly concerning different threats to validity.

Four threats to validity are referred to in the following [48].

1) *Conclusion validity*

The subjects are expected to deliver a lot of data when solving the modeling task. Thus, there is a risk that the data is not correct due to mistakes, e.g., a bad experimental design. Possible data inconsistencies are, however, not believed to be particularly related to the background or application experience of the subject. The conclusion validity is therefore not considered to be critical.

2) *Internal Validity*

Internal validity refers to the issue that the treatment causes the outcome, i.e., make sure that it is not a factor which cannot be controlled [46]. The internal validity of the empirical study is ensured by keeping the extraneous variables at fixed levels (cf. Fig. 1).

3) *Construct validity*

In the authors' opinion, the chosen dependent variables are appropriate measures to investigate the hypotheses H1 to H5.There is no empirical evidence that modelers having different application experience perform differently in process modeling. The important issue for the empirical study is that there is a proven difference in application experience, and the actual size of the difference between the group I subjects and the group III subjects is of minor importance.

4) *External Validity*

With regard to the external threats, it is highly probable that the results of the group I subjects are obtained with similar subjects from corporate practice which have practical experience.

Sample size is very small and the sample only consists of research assistants. Future research should collect data from practitioners who might follow other working methods.

A further difference to process modeling in corporate practice is that relevant process information could be recalled by a subject at any time during the laboratory study by simply reading up the task. In a real word setting the modeler might chose another working method due to situational factors.

D. *Discussion*

With regard to model development time, experienced modelers developed the process models on average faster than novices.

A statistically significant difference between the groups was found for time for mental activities and time for labeling. Experienced modelers did not need as much time for mental activities as modelers with less application experience. In contrast experienced modelers spent more time on labeling.

They seemed to have a better understanding of what is relevant for the information content of a process model and incorporate this information more conscientious into the process model. Experienced process modelers achieved higher consistency with the predefined sample solutions whereas novices left out more information and developed process models with less information content.

Regarding activity labeling style, the modelers with the highest application experience seemed to have a preference for verb-object activity labeling (83.19%). The group III subjects also preferred verb-object labeling style (60.87%), although with a much lower percentage. The group II subjects had generally more variety in their labeling style and a slight preference for the action-noun labeling style. The corresponding activities may be misinterpreted by a model user and might lead to inadequate working procedures. These results empirically support the findings from [18] and a previous study [49].

IV. Conclusion and Outlook

Methods of industrial engineering such as PMTS bear the potential to investigate and improve working methods in process modeling. The study presented in this paper accounted for the aspect of the modeling method and thereby contributes to a still limited body of knowledge on working methods in process modeling. The findings might have the potential to further enhance human performance in process modeling.

With a prospect on future research and from an industrial engineering point of view, this research has implications in terms of technical, organizational and personnel issues [50], [51]. Technical issues are related to the modeling tool, e.g., how a modeling tool can support working according to the identified working methods. Organizational issues are mainly related to training concepts in process modeling. Personnel issues are related to the modeler and his set of abilities and skills.

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