# How Advanced Change Patterns Impact the Process of Process Modeling*

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**Abstract.** Process model quality has been an area of considerable research efforts. In this context, correctness-by-construction as enabled by change patterns provides promising perspectives. While the process of process modeling (PPM) based on change primitives has been thoroughly investigated, only little is known about the PPM based on change patterns. In particular, it is unclear what set of change patterns should be provided and how the available change pattern set impacts the PPM. To obtain a better understanding of the latter as well as the (subjective) perceptions of process modelers, the arising challenges, and the pros and cons of different change pattern sets we conduct a controlled experiment. Our results indicate that process modelers face similar challenges irrespective of the used change pattern set (core pattern set versus extended pattern set, which adds two advanced change patterns to the core patterns set). An extended change pattern set, however, is perceived as more difficult to use, yielding a higher mental effort. Moreover, our results indicate that more advanced patterns were only used to a limited extent and frequently applied incorrectly, thus, lowering the potential benefits of an extended pattern set.

**Key words:** Process Model Quality, Process of Process Modeling, Change Patterns, Controlled Experiment, Problem Solving

## 1 Introduction

Due to the important role they play for process–aware information systems, process models have become increasingly important for many years [1]. In this context, it was shown that process model understandability has a measurable impact on whether or not a process modeling initiative is successful [2]. Still, process models exhibit a wide range of quality problems, which not only hamper comprehensibility but also affect maintainability [3, 4]. For example, [3] reports on error rates between 10% and 20% in collections of industrial process models.

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To improve process model quality, change patterns appear promising. They combine change primitives, e.g., to add nodes or edges, to high-level change operations [4]. In particular, change patterns enable correctness-by-construction [6] by providing only those change patterns to the modeler, which ensure that process models remain sound after applying model transformations.

Recently, the creation of process models based on change primitives has received considerable attention resulting in research on the *process of process modeling (PPM)* [7, 8, 9]. This research focuses on the *formalization* phase of process model creation, i.e., the interactions of the process modeler with the modeling environment. The PPM utilizing change patterns, in turn, is still hardly understood. In previous work we presented an exploratory study to investigate re-occurring challenges when using change patterns for process modeling [10]. The study revealed that process modelers did not face major problems when using change patterns for constructing simple process fragments. When being confronted with more complex process fragments, however, difficulties increased observably. Building respective structures efficiently (i.e., without *detours* in the PPM) requires process modelers to look ahead, since patterns cannot be always combined arbitrarily. This need for looking ahead is a fundamental difference compared to process model creation based on change primitives and was perceived as both challenging and restrictive by subjects. Further, [10] emphasizes that the basic set of change patterns, which allows creating control flow structures like sequence, exclusive branchings, parallel branchings, and loops, is not sufficient for efficient model creation. In particular, the study observed that patterns for moving process fragments might help to resolve detours efficiently.

On one hand, an extended set of change patterns (including move patterns) offers more flexibility. On the other, it increases complexity, especially when mapping the mental model of the process to be created to the available pattern set. As a result, the extended change pattern set might make the modeling environment more difficult to use. This raises the question whether the expected benefits of an extended pattern set can be materialized in a practical setting. To obtain an in-depth understanding of the impact an extended pattern set has on the PPM, we implement a modeling editor offering two different change pattern sets based on Cheetah Experimental Platform (CEP) [11]. Using this editor, we conduct a controlled experiment with 42 process modelers. Our results indicate that an extended pattern set yields higher mental effort for modelers and is perceived as more difficult to use. At the same time, the expected benefits in terms of increased problem solving efficiency did not materialize, suggesting to focus on a core pattern set. The results provide a contribution toward a better understanding on how tool features (like change patterns) impact the PPM, but also give advice on how effective tool support should be designed.

Sect. 2 introduces backgrounds. Sect. 3 describes the controlled experiment. Sect. 4 presents the subjective perception of change pattern use. Sect. 5 deals with the impact of change patterns on problem solving efficiency and Sect. 6 details on the actual and potential use of patterns. Limitations are presented in Sect. 7. Related work is presented in Sect. 8. Sect. 9 concludes the paper.

## 2 Process Model Creation Based on Change Patterns

Most environments for process model creation are based on change primitives, e.g., `add/delete activity` or `add/delete edge`. Process model adaptations (i.e., transformation of a model S into model S') may require the joint application of multiple change primitives. Imagine process model $S_1$ in Fig. 1 without the colored fragment. To transform this model into S1 (including the colored fragment) 19 change primitives are needed: deleting the edge between activity `D` and the parallel gateway, adding `D`,`E`, and `F` to the process model, adding the conditional branch around `C` (including transition conditions), and adding the edges connecting the newly added elements with the process model. When applying change primitive, soundness of the resulting process model cannot be guaranteed and must be explicitly checked after every model transformation. In turn, change patterns imply a different way of interacting with the modeling environment. Instead of applying a set of change primitives, high-level change operations are used to realize the desired model transformation. Examples of change patterns include the insertion of process fragments, their embedding in conditional branches or loops, or the updating of transition conditions. A catalog of change patterns can be found in [4], while their semantics of these patterns are described in [5]. To conduct the described transformation with change patterns (i.e., obtain $S_1$ from a model where the colored fragment is missing), 6 pattern applications are needed (i.e., serial insert of activity `E`, parallel insert of activity `F`, serial insert of activity `C`, embed activity `C` in conditional branch, and two updates of conditions). As opposed to change primitives, change pattern implementations typically guarantee model correctness after each transformation [6] by associating pre-/post-conditions with high-level change operations. In process modeling environments supporting the correctness–by–construction principle (e.g., [12]), usually process modelers only have those change patterns available for use that allow transforming a sound process model into another sound one. For this purpose, structural restrictions on process models (e.g., block structuredness) are imposed. This paper investigates the impact of two different change pattern sets on the PPM.

## 3 Experiment

This section describes research questions and the design of the experiment.

**Research Questions.** Our goal is to obtain an in-depth PPM understanding when using change patterns. More specifically, we want to understand how modelers experience their interaction with the modeling environment depending on the available change pattern set.

> RQ1: What is the impact of the change pattern set available to process modelers on their subjective perception during model creation?

In addition to the subjective perception of modelers, we are interested in the challenges faced by process modelers during the PPM depending on the used change pattern set. Respective challenges can result in modeling errors that persist in the final model, but also detours on the way to a complete process model, negatively affecting problem solving efficiency.

> RQ2: What is the impact of the change pattern set available to process modelers on the challenges faced during model creation?

Finally, we want to understand how well the additional patterns of the extended pattern set was adopted (i.e., in their actual use) as well as the potential benefits that could have been achieved through proper pattern usage.

> RQ3: What was the actual use of the additional change patterns compared to the potential of using those patterns?

**Factors and Factor Level.** The experiment considers a single factor, i.e, the pattern set used to conduct the modeling task with factor levels: *core* and *extended*. The core pattern set comprises a minimum change pattern set (see [4] for the full pattern set) that allows modelers to create basic control-flow structures (i.e., sequences, parallel, conditional branchings, and loops): patterns AP1 (Insert Process Fragment), AP2 (Delete Process Fragment), AP8 (Embed Fragment in Loop), AP10 (Embed Process Fragment in Conditional Branch), and AP13 (Update Condition). Concerning pattern AP1, two variants were provided: Serial and Parallel Insert. In addition, process modelers could rename activities. In turn, the extended pattern set comprises all patterns included in the core pattern set plus an advanced pattern for moving process fragments (AP3). To be able to trace back the impact to single change patterns, we intentionally decided to only add one additional pattern from which we expect a considerable impact on problem solving efficiency to the extended pattern set. Similar to AP1, two variants are provided: Serial and Parallel Move. While the core pattern set is complete in the sense that all control-flow structures can be created, it does not allow for arbitrary model transformations. In particular, in [10] we observed that detours could have been addressed more efficiently with an extended pattern set. In particular, we observed that patterns for moving process fragments would have helped with many of the detours. Frequently, process modelers had to undo or delete considerable parts of the model, which could have been resolved with the application of a single move pattern. Consider, for example, the two models in Fig. 1. When transforming $S_1$ to $S_2$ without move patterns, the modeler must perform a detour of 7 steps to delete the colored parallel branch and to re-insert it after activity B (cf. problem solving path $P_{1,2}$). On the contrary, using move patterns, transforming $S_1$ into $S_2$ just requires the application of one change pattern, i.e., Serial Move, saving a total of 6 pattern applications.

**Modeling Tasks.** The modeling task is a slight adaption of the task used in [10] and describes a process of the "Task Force Earthquakes" of the German Research Center for Geosciences [13] (cf. Fig. 2—labels are abstracted for readability). The task comprises 15 activities; all main control–flow structures like sequence, parallel and conditional branchings, and loops are present. The model

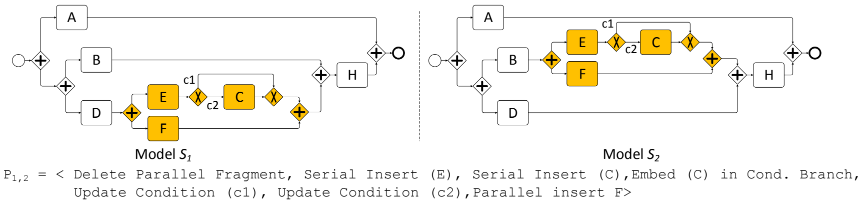



**Fig. 1.** Detour to go from $S_1$ to $S_2$ when no Move Patterns are available

has a nesting depth of 4. Subjects received an informal requirements description as well as the solution of the modeling task (i.e., a process model). Their task was to re–model the process using change patterns. To model the process a minimum number of 28 change patterns are required with both the core and the extended change pattern set. Since subjects had the correct solution available, the challenge lies in determining the patterns for re-constructing the model and in combining the available patterns effectively.

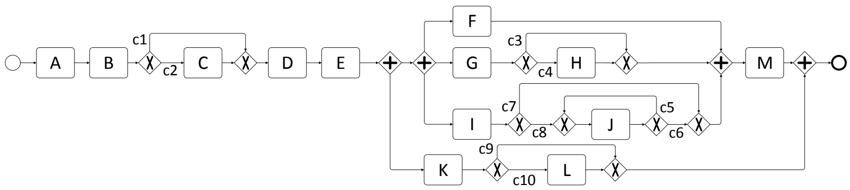



**Fig. 2.** Solution Model $S_S$

**Subjects.** Novices and experts differ in their problem solving strategies. Considering that industrial process modelers are often not expert modelers, but rather casual modelers with a basic amount of training [14], subjects participating in our experiment are not required to be experts. In previous research with software engineering students it has been shown that students can provide an adequate model for the professional population [15, 16, 17]. Thus, we relied on students (instead of professionals) in our experiment. To avoid difficulties due to unfamiliarity with the tool, rather than the modeling task, we require some prior experience with process modeling as well as change patterns. To ensure that the subjects are sufficiently literate in change pattern usage, subjects are provided with theoretical backgrounds. Further the subjects obtain hands-on experience in the creation of process models using change patterns in terms of a familiarization task.

**Experimental Setup.** The experiment consists of four phases. (1) collecting demographic data, (2) familiarization with the change patterns editor, and (3) performing a modeling task. Subjects were divided into two groups. While *Group A* receives the core pattern set, *Group B* conducts the same task based on the extended pattern set. During modeling, all interactions with the modeling environment are recorded by CEP [11]. This allows us to replay the creation of the process model step-by-step [11], addressing RQ2 and RQ3. After completing the modeling tasks, (4) *mental effort* as well as *Perceived Ease of Use (PEU)* and

*Perceived Usefulness (PU)* of the *Technology Acceptance Model* [18] are assessed, addressing RQ1.

**Experimental Execution.** Prior to the experiment a pilot was conducted to ensure usability of the tool and understandability of the task description. This led to improvements of CEP and minor updates of the task description. The experiment was conducted by 42 graduate and postgraduate students from the Universities of Innsbruck, Ulm, and Valencia. Subjects were randomly assigned to groups, with an equal number of subjects for each group.

**Data Validation.** To obtain a valid data set, we checked for completeness of the created process models. Unfortunately, 8 of the participants had to be removed due to incomplete models. As, a result, 34 subjects remained in the data set, which were equally distributed over the two groups. Since we did not consider process modeling knowledge and experience as a factor in our experiment, we screened the participants for prior knowledge regarding BPMN and change patterns. For this, a questionnaire similar to [19] was used to verify that subjects were equally distributed to the two groups. (cf. Table 1). The questionnaire used Likert scale ranging from strongly disagree (1) to strongly agree (7). To test for differences between the two groups, t-tests were run for normally distributed data. For non–normally distributed data, the Mann-Whitney test was used. No significant differences were identified between the two groups. Consequently, we conclude that no differences could be observed between the two groups.

| Question | Group | Min | Max | M | SD |
|---|---|---|---|---|---|
| Familiarity with BPMN | A | 2 | 7 | 5.12 | 0.99 |
| | B | 2 | 7 | 5.53 | 1.28 |
| Confidence in understanding BPMN | A | 3 | 7 | 5.53 | 1.33 |
| | B | 4 | 7 | 6.24 | 0.75 |
| Competence using BPMN | A | 3 | 7 | 5.06 | 1.14 |
| | B | 3 | 7 | 5.59 | 1.06 |
| Familiarity change patterns | A | 2 | 7 | 4.76 | 1.44 |
| | B | 2 | 7 | 4.53 | 1.46 |
| Competence using change patterns | A | 2 | 7 | 4.59 | 1.33 |
| | B | 2 | 6 | 4.41 | 1.28 |

**Table 1.** Demographic Data

## 4 Subjective Perception of Model Creation

This section addresses research question RQ1 dealing with the subjective perception of process modelers when using change patterns. In particular, it investigates how the used change pattern set (core vs. extended) impacts mental effort. Further, we investigate the perceived ease of use and perceived usefulness.

### 4.1 Mental Effort

*Descriptive Statistics.* The results related to mental efforts are displayed in Table 2. Mental effort was measured using a 7-point Likert scale ranging from 'very low' (1) to 'very high' (7). For Group A the mean mental effort was 3.35, corresponding approx. to 'rather low' (3). In turn, for Group B the mental effort was higher with a mean of 4.25, corresponding to 'medium' (4).

| Scale | Group | Min | Max | M | SD |
|---|---|---|---|---|---|
| Mental Effort | A | 2 | 5 | 3.35 | 1.06 |
| | B | 3 | 7 | 4.25 | 1.00 |
| Perceived Ease of Use | A | 5.18 | 6.06 | 5.81 | 0.33 |
| | B | 4.53 | 5.82 | 5.25 | 0.47 |
| Perceived Usefulness | A | 4.13 | 4.75 | 4.38 | 0.21 |
| | B | 3.87 | 4.87 | 4.27 | 0.36 |

**Table 2.** Subjective Perception

*Hypothesis Testing.* When using change patterns for process modeling, plan schemata on how to apply change patterns need to be developed in order to create complex process fragments. In this context, we investigate how the mental effort of modelers is affected by utilizing a larger change pattern set. While the extended change pattern set allows modelers to recover faster from detours, it also requires them to develop additional plan schemata on how to apply the move change patterns. Therefore, an extended change pattern set might impose higher demands on the modeler's cognitive resources. Especially, move change patterns require modelers to imagine how the process model looks like after applying change patterns. This might put additional burden on them, requiring to manipulate an internal representation of the process model in working memory. In the light of the cognitive background, we expect the extended pattern set to yield a significantly higher mental effort compared to the core pattern set.

**Hypothesis H1** *The usage of an extended change pattern set significantly increases the mental effort required to accomplish the modeling task.*

Since the data was normally distributed, a t-test was used for testing the differences between the two groups ($t(31) = -2.50, p = 0.02$). The result allows us to accept hypothesis H1.

*Descriptive Statistics.* In order to assess how far process modelers with moderate process modeling knowledge consider the change pattern editor as easy to use and useful, we asked them to fill out the *Perceived Ease of Use (PEU)* and the *Perceived Usefulness (PU)*. Both scales consist of 7-point Likert items, ranging from 'extremely unlikely' (1) over 'neither likely nor unlikely' (4) to 'extremely likely' (7). Regarding the PEU, the mean value was 5.81 for Group A (core pattern set), corresponding approx. to 'quite likely' (6). In turn, for Group B (extended pattern set) the mean value was 5.25, corresponding approx. to 'slightly likely' (5). Finally, regarding the PU, the observed mean value was 4.38 for Group A and 4.27 for Group B, corresponding approx. to 'neither likely nor unlikely' (4) for both groups. Three participants indicated that they could not answer the questions on PU. Hence, they were removed for the analysis of PU.

*Hypothesis Testing.* As stated for mental effort already, the extended pattern set requires modelers to develop additional plan schemata in order to apply the change patterns properly. Accordingly, one would expect that an extended change pattern set is more difficult to use. However, these should also be perceived as more useful since the extended pattern set helps to resolve detours quicker compared to the core pattern set, i.e., when allowing to move a misplaced process fragment based on a respective pattern.

**Hypothesis H2** *The usage of an extended change pattern set significantly lowers the perceived ease of use.*

**Hypothesis H3** *The usage of an extended change pattern set significantly increases the perceived usefulness.*

Since none of the groups are normally distributed, we apply the Mann-Whitney U-Test to test for differences regarding PEU and PU. While significant differences in terms of PEU ($U = 4010.50, p = 0.00$) allow us to accept hypothesis H2, no statistically significant differences in terms of PU ($U = 3639.00, p = 0.06$) were observed.

*Discussion.* Our results indicate that the core pattern set leads to a significantly lower mental effort for modelers and its use is perceived as being significantly easier compared to the extended pattern set. This seems reasonable since modelers need to devote additional cognitive resources in order to use the move change patterns. Regarding PU, against our expectations, we could not obtain any statistically significant result. When looking at the descriptive statistics, the participants of Group B tend to perceive change patterns as less useful compared to Group A. We might conclude that the move change patterns provided for Group B are not as useful as expected (at least for the task assigned to the subjects). Alternatively, the subjects of Group B might have struggled with the usage of change patterns due to the additional patterns. In turn, this might have foiled potential positive effects of the additional patterns. The results presented in Sec. 5 support the latter explanation suggesting that process modelers had considerable problems with the use of the move patterns.

## 5 Challenges when Modeling with Change Patterns

This section addresses research question RQ2 aiming to obtain an in-depth understanding how the chosen pattern set impacts the challenges faced by modelers.

### 5.1 Data Analysis Procedure

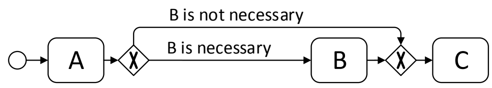
*Step 1: Determine Solution Model, Distance, and Optimal Problem Solving Paths.* First, we create a model representing the correct solution (i.e., $S_S$) for the modeling task. Subjects had to work on a re-modeling task as described in Sect. 3, i.e., in addition to an informal textual description they obtained the solution to the modeling task in the form of a graphical model. Thus, the goal state of the modeling task was clearly defined and unique, i.e., subjects should create a graphical representation of the process that exactly looks like the solution model. To be able to assess not only how closely subjects reached the goal state (i.e., how similar their resulting model is to the solution model), but also how efficiently their problem solving process was, we determine the *distance* for transforming an empty model $S_0$ to $S_S$, i.e., the minimum number of change patterns required for the respective model transformation. Generally, there are several options to create the solution model $S_S$ by starting from $S_0$ and applying a sequence of model transformations. From a cognitive perspective, each sequence of change patterns that leads to $S_S$ without detours constitutes an *optimal problem solving path*. Starting from $S_0$ the process fragment depicted in Fig. 3 can be created with 6 change patterns; e.g., $S_S$ can be created by first inserting $A$ and then $B$, next embedding $B$ in a conditional branch, then updating the two transition conditions, and finally inserting $C$ ($P_0$ in Fig. 3).

*Step 2: Determine Deviations from Solution Model and Optimal Problem Solving Path.*

To quantify the efficiency of the problem solving strategy used by the subjects to accomplish the re-modeling task, their problem solving path is analyzed. To be more specific, using the replay feature of CEP we compare the subject's problem solving path $P$ with the optimal one and capture deviations from it. For this, every superfluous change pattern application a subject performs is counted as a *process deviation*. To quantify how close subjects reached the goal state (i.e., how similar their resulting model is to the solution model $S_S$) we consider *product deviations* that measure the number of incorrect change pattern applications leading to deviations between the final models created by the subjects and the solution model $S_S$.

Fig. 3 shows the problem solving path $P_0$ of one modeler who managed to model the depicted fragment correctly (i.e., 0 process deviations and 0 product deviations). Problem solving path $P_2$, in turn, leads to a correct goal state (i.e., 0 product deviations). However, the modeler made a detour of 2 change patterns before reaching the solution (i.e., solution path $P_2$ comprises 2 superfluous change patterns summing up to 2 process deviations). Now assume that the modeler, who took a detour when creating the process model, did not correct the introduced error ending up with an incorrect process model (cf. path $P1$ in Fig. 3). The application of the Embed in Loop pattern (instead of Embed in Conditional Branch) constitutes 1 product deviation (i.e., the modeler applied one incorrect change pattern that led to an incorrect goal state).

Since not every subject reached the goal state (i.e., their models contain product deviations), the direct comparison of process deviations might favor modelers that left out parts that were difficult to model and where other subjects produced a high number of process deviations. To decrease this bias we consider a second measure for operationalizing problem solving efficiency. In addition to the process deviations described above this measure considers the effort needed to correct an incorrect process model (denoted as *fixing steps*), i.e., the steps needed to transform the created model into $S_S$. For example, to correct the model that resulted from $P1$ in Fig. 3, 5 fixing steps are needed, irrespective of whether or not the core or the extended change pattern set is used. First the fragment embedded in the loop has to be deleted. Next, $B$ has to be re-inserted and embedded in a conditional branch, and then the two transition conditions must




$P_0$ = < Serial Insert (A), Serial Insert (B), Embed (B) in Cond. Branch,
Update Condition (B is not necessary),
Update Condition (B is necessary), Serial Insert (C) >

$P_1$ = < Serial Insert (A), Serial Insert (B), Embed (B) in Loop,
Update Condition (B is not necessary),
Update Condition (B is necessary), Serial Insert (C) >

$P_2$ = < Serial Insert (A), Serial Insert (B), ~~Embed (B) in Loop~~,
~~Undo Embed (B) in Loop~~, Embed (B) in Cond. Branch,
Update Condition (B is not necessary),
Update Condition (B is necessary), Serial Insert (C) >

**Fig. 3.** Process Deviations, Product Deviations, and Fixing Steps

be updated. Fixing steps and process deviations are then combined in a single measure called *total process deviations*. This measure does not only consider detours (i.e., process deviations), but also model transformations that would be needed to correct the process model (i.e., resolving product deviations).

*Step 3: Detection of Outliers.* In order to limit the influence of modelers who are experiencing severe difficulties during the creation of the process model, we test for outliers regarding the number of process deviations. For this purpose, we utilize the Median Absolute Deviation (MAD) to detect outliers. More specifically, we apply a rather conservative criterion for removing outliers by removing values that differ at least 3 times the MAD from the median [20]. As a result, one PPM instance was removed from Group B regarding further analysis.

### 5.2 Results

*Descriptive Statistics.* To create a correct solution model 28 operations are needed. Overall, 123 process deviations (i.e., detours in the modeling process) and 44 product deviations (i.e., deviations of the final models from the solution model) were identified (cf. Table 3). From the 123 process deviations 60 can be attributed to Group A (3.53 deviations per subject), while 63 were found for Group B (3.94 deviations per subject). In terms of product deviations they were equally distributed among the two groups, i.e., 22 product deviations per group (1.29 deviations per subject in Group A and 1.38 deviations per subject in Group B). In order to resolve the product deviations, 45 fixing steps are required for the models of Group A and 29 fixing steps for Group B resulting in 105 and 92 total process deviations respectively.

*Hypothesis Testing.* We test for significant differences between the two groups regarding process deviations and total process deviations. We expect that the modelers using the extended pattern set have significantly fewer process deviations, because the extended pattern set allows them to resolve detours with fewer steps. Moreover, we expect an impact on the total process deviations, since the

| Scale | Group A | Group B |
|---|---|---|
| Process deviations | 60 | 63 |
| Average Process deviations per modeler | 3.53 | 3.94 |
| Product deviations | 22 | 22 |
| Average Product deviations per modeler | 1.29 | 1.38 |
| Fixing steps | 45 | 29 |
| Average fixing steps per modeler | 2.65 | 1.81 |
| Total process deviations | 105 | 92 |
| Average total process deviations per modeler | 6.18 | 5.75 |

**Table 3.** Overview of Deviations

extended pattern set allows transforming the model created by the modelers with fewer steps into the solution model.

**Hypothesis H4** *The usage of an extended change pattern set significantly decreases the number of process deviations.*

**Hypothesis H5** *The usage of an extended change pattern set significantly decreases the number of total process deviations.*

To test for differences in terms of process and total process deviations, we apply the t-test since the data was normally distributed. No statistical difference could be observed for process deviations ($t(31) = -0.24, p = 0.82$) or total process deviations ($t(31) = 0.25, p = 0.81$).

*Discussion.* Our results did not yield statistically significant differences between the two groups. This indicates that the usage of an extended change pattern set might not have an impact on both process deviations and total process deviations. An alternative explanation could be that process modelers did not use the provided patterns frequently enough to obtain statistically significant differences (i.e., pattern adoption was low). Another explanation could be that subjects did not use the patterns effectively, canceling out a potential positive impact. To investigate these alternative explanations in more detail Sect. 6 analyzes the actual use of the move change patterns.

## 6 Actual and Potential Use of an Extended Pattern Set

This section addresses research question RQ3 which deals with the actual use of the additional change patterns compared to the potential usage of those patterns. The analysis of invocations of the move change patterns revealed that the serial move pattern was only applied 3 times (by 3 different participants), whereas the parallel move pattern was used 18 times (by 7 different participants). This indicates that the subjects adopted the move patterns only to a limited extend. Out of the 21 move pattern applications, 11 were correct; i.e., they led to correct intermediate models, either directly through the application of the pattern or the application of the pattern in combination with additional patterns. In turn, 10 applications of the parallel move pattern were incorrect and either led to an undesired model or did not yield any changes of the model. This indicates that subjects had difficulties when applying the move change patterns.

Though the actual use of the move patterns was limited, we investigate their theoretical potential. For this, we analyze the number of fixing steps required to correct a model with product deviations (i.e., to transform it into $S_S$). We further analyze how the availability of an extended pattern set impacts this measure. In a second step, we analyze the potential of an extended pattern set for reducing process deviations, i.e., by enabling a faster resolution of detours.

| Scale | Group A | Group B |
|---|---|---|
| Fixing steps with move | 45 | 64 |
| Fixing steps without move | 25 | 29 |
| Saved operations | 20 | 35 |
| Process Deviations | 60 | 63 |
| Unnecessary Operations | - | 15 |
| Saved operations | 9 | 0 |
| Potential process deviations | 51 | 48 |

**Table 4.** Potential Use of the Move Change Pattern

To show the potential of an extended pattern set for resolving product deviations, Table 4 depicts the number of fixing steps, when using the core pattern set and for the extended pattern set. For Group A, 45 fixing steps are required to correct all product deviations that occurred. By making the extended pattern set available to Group A, this number could be reduced to 25 (i.e., 20 fixing steps could be saved). In turn, for Group B the number of observed fixing steps is 29. Without the extended pattern set, however, 64 fixing steps would be needed. This indicates the theoretical potential of the extended pattern set for reducing the number of fixing steps and, thus, the number of total process deviations.

To investigate the potential for reducing process deviations for Group A, we analyze whether process deviations could have been reduced when using move change patterns. In turn, for Group B we focused on the number of operations that would have been saved if move patterns were always applied correctly. As illustrated in Table 4, 9 operations could be saved if the move pattern had been available for Group A resulting in 51 potential process deviations. Regarding Group B, 15 operations could have been saved through correct pattern application resulting in 48 potential process deviations.

*Discussion.* These results suggest that a theoretical potential for using move change patterns exists. However, the subjects used the move change patterns only to a limited extent and had troubles with their correct application. As a consequence the potential of the additional patterns could not be fully exploited. Since mental effort and perceived ease of use is lower with the core pattern set it might be more favorable to use the core pattern set for process modelers that are only moderately familiar with process modeling and are no experts in the usage of change patterns. We might speculate that the extended pattern set could be promising for more experienced users (who are literate in pattern usage).

## 7 Limitations

As with every other research, this work is subject to several limitations. Certainly, the relatively small sample size constitutes a threat regarding the generalization of our results. Using students instead of professionals poses another threat regarding external validity. In previous research with software engineering students it has been shown that students may provide an adequate model for the professional population [15, 16, 17]. Still, generalizations should be made with care. Moreover, since we used subjects who were moderately familiar with process modeling and change patterns results cannot be generalized to expert modelers. It can be assumed that process modelers experienced with the usage of change patterns will presumably face less problems during model creation and will be able to apply patterns more effectively. Another limitation relates to the fact that we used only one modeling task in our study. The potential benefit of move patterns, however, depends on the structure of the process model to be created. For more complex process models with higher nesting depth the potential usefulness might be higher. Thus, it is questionable in how far results may be generalized to models with different characteristics. As a consequence, we plan further experiments testing the impact of model structure on challenges regarding change pattern usage. Moreover, this work compares two particular change pattern sets. Using an extended change pattern set with different patterns (e.g., a pattern to change a conditional fragment into a parallel fragment or to change a conditional fragment to a loop) might lead to different results. Another limitation regarding the external validity relates to the process modeling notation (i.e., BPMN) and the modeling tool used (i.e., CEP). Results might be different when using other modeling languages or different modeling tools.

## 8 Related Work

The presented work relates to research developed in the context of the creation of process models and process model creation patterns.

Research on the creation of process models builds on observations of modeling practice and distills normative procedures for steering the process of modeling toward successful completion. To do so, [21, 22] deal with structured discussions among different parties (system analysts, domain experts). In this line of research, [23] analyzes the procedure of developing process models in a team, while [24] discusses participative modeling. Complementary to these works, whose focus is on the effective interaction between the involved stakeholders, our work focuses is on the *formalization* of the process model.

Researchers have also focused on the interactions with the modeling environment, i.e., the PPM. [9] identified three distinct modeling styles, whereas [7, 25] suggest different visualization techniques for obtaining an overview of the PPM; [8] demonstrates that a structured modeling style leads to models of better quality. [26] investigates the PPM using eye movement analysis. While these works focus on interactions with the modeling environment based on change primitives, this paper investigates the use of change patterns.

Change patterns for process model creation have been investigated as well; e.g., AristaFlow allows modeling a sound process schema based on an extensible set of change patterns [12]. [27] describes a set of pattern compounds, comparable to change patterns, allowing for the context-sensitive selection and composition of workflow patterns. Complementary to these works, which have a strong design focus, this paper provides empirical insights into the usage of change patterns. More precisely, it builds upon the results obtained in [10], which describes recurring challenges modelers face during the PPM using change patterns.

## 9 Summary

While recent research has contributed to a better understanding regarding the PPM, little is known about this process when utilizing change patterns. In this experiment we investigate the impact of the available patterns on the PPM and the modeler's perception. The results indicate that an extended change pattern set puts an additional burden on modelers who perceive them as more difficult to use. In addition, when using these patterns, subjects faced considerable difficulties. Therefore, (against our expectations) our data does not indicate an increased problem solving efficiency, i.e., the expected benefits of using the extended change pattern set did not materialize. This indicates that the change pattern set should be selected with care, especially for modelers with limited experience. Future research should include investigations on new change pattern sets having a (theoretical) potential for reducing process deviations, e.g., a pattern to change a conditional fragment into a parallel or a loop fragment.

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