Advancing the BPMN 2.0 standard with an extended animated notation: a research program for token-based process modeling education

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Abstract
With BPMN 2.0 as a de facto standard, (business) process modeling is critical in effectively managing organizations, spearheading digitalization projects, and fostering innovations. Despite its widespread use, professionals' modeling abilities could be further improved by implementing an effective (business) process modeling training program in higher education. To accomplish this, the paper proposes a teaching and learning technique involving animation, visualization, and simulation based on using tokens in process models. In particular, the paper outlines a four-stage research program, with some preliminary findings presented and discussed. These stages encompass experimental research, a mixed methods approach, and the utilization of eye-tracking analysis, ultimately developing an initial theoretical framework for token-based process modeling education. Furthermore, the paper proposes future research avenues.

Keywords
Process modeling education, BPMN, process model tokens, visualization, animation, simulation, research program proposal, TAM, PLS-SEM, eye-tracking, theory formulation.

1. Context and motivations

(Business) Process Modelling (thereon, PM) transforms textual requirements into visual and formally structured representations. The primary objectives of PM encompass enhancing communication between business and IT personnel, providing clear insights to employees regarding their roles within processes, refining or re-engineering existing processes, and enabling process automation through enterprise information systems. In organizational contexts, numerous business processes catering to diverse business functions can be found [1]. BPMN 2.0 is a de facto standard formalism for PM [1], even though other PM languages exist, like Petri Nets, and UML-Activity Diagrams, with varying degrees of usability [2] The deliberate training of process modelers can enhance the acquisition of essential skills necessary for effective PM, thereby addressing the prevalent problem of subpar process model quality within organizations [3]. The increasing demand for proficient process modelers has elevated the significance of investigating practical pedagogical approaches in the PM domain, as evident in the research endeavors of [4]–[6]. Considering the initial levels of Bloom's taxonomy, process modeling learning may start with comprehending the process models [7]. Still, considerable challenges exist, including the complexity of models, lack of experience and domain knowledge, motivation to read process models profoundly, lack of tool support and validation procedures, and inability to change the user's characteristics at a given point of reading a model [7]–[12]. PM is an inexact skill involving specific cognitive schemata and experience [9].

To address the challenges of learning PM, literature proposed the use of visualization, animation, and simulation of process models [5], [9], [10], [12]–[14]. Animation of BPMN process

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models through tokens (an idea similar to that of Petri nets process models), which is a representation of a (business) process instance, has been proposed as a promising approach [15]–[17]. Using tokens can contribute to the clarification of process behavior, distinguish between an abstract model and its specific instances, and act as a cognitive aid for modelers [18]. As a result, this approach reduces the cognitive burden on modelers [19], [20] and enhances the comprehension of BPMN language elements, leading to a more insightful model [5]. Even though using tokens has been named a very effective technique to convey the dynamic aspects and logic of the processes, to the best of our knowledge, there is a lack of evidence-based research exploring using tokens as a basis for teaching process modeling. The main research objective for the program is to fill this gap and move towards a systematic and empirically validated educational approach to Token-Based Process Modelling (TBPM).

Tokens are a supplementary notation that complements the BPMN 2.0 formalism [10]. A modeling tool or environment is required to use such notation in education and research. However, tools that support TBPM are scarce and lack sufficient functionalities to help TBPM fully. Examples include Camunda or the MIDA application based on Camunda [17] and a tool proposed by [21] that can simulate process instances. Further developing or improving such tools aligns with the recent trend of developing domain-specific modeling languages and meta-modeling to fit better the demands of the modelers [22], who are PM educators in our approach.

In this positional research paper, we first present the proposed research program, encompassing the four stages of the research with the respective research objectives, methodologies, and (preliminary) findings. Finally, we present conclusions, a discussion section, and the proposed research agenda for the identified problems.

2. Proposed research program for the TBPM education

Table 1 displays the four research stages we have completed or plan to undertake. We provide detailed descriptions of the intended papers, outlining their research questions, methodologies, and the (preliminary) findings. We have submitted two studies to peer-reviewed journals and received a first 'major revision' review. We collected the data for the third and fourth stages and performed preliminary data analyses.

Table 1
Stages of the research program to move towards TBPM education

Research stage	Research objective(s)	Research methodology	(Preliminary) findings
Controlled experimentation of the comprehension of static process models versus TBPM	To explore whether the token-animated BPMN process models are better comprehended than static models.	(1) Design of an additional notation for BPMN (token-based process modeling) in PowerPoint. (2) Controlled survey experiment: quantitative test data evaluated with statistical significance testing.	(1) Token-animated process models are significantly better comprehended than static models. (2) The effectiveness of comprehension also significantly depends on the (cognitive) resources of the students, forming a distributed cognition system.
Technology acceptance of TBPM for learning purposes	(1) To understand whether the students accept the token-based process	(1) SEM-PLS theoretical framework confirming quantitative TAM	(1) Token-animated process models are accepted as valid tools with a high preference for static process models for

	models as potential users. (2) To get feedback from students concerning the potential usage of tokens.	data (2) Qualitative feedback evaluation concerning the applications, benefits, and use of TBPM education	learning purposes. (2) Usage of token-animated process models must consider the students' different potential usage patterns.
Identifying generic visual patterns and typical interactions of students with token-animated process models	To understand the visual patterns and connect them to the interaction patterns of the students	(1) Quantitative test results data (2) Visualized eye-gazing patterns of PM students (3) Quantitative data analyzing eye-gazing patterns (4) Qualitative feedback from the students.	(1) There are significant differences in how the students use tokens to comprehend process models compared to the static models. (2) We suggest certain patterns that can be taught to the students using tokens, which may have a potential spill-over (learning) effect on perception patterns.
Establishing a (preliminary) theoretical framework for the TBPM education	To create an initial theoretical framework for using TBPM in the instructional design for PM	(1) Mainly based on the qualitative feedback of the students, as well as facilitated with literature findings and suggestions (2) Supported by the data and examples of the past stages	From the quantitative, qualitative, and eye-tracking pattern analysis, we suggest an early theoretical framework of how educators may better structure the process of modeling education.

2.1. Controlled experimentation of the comprehension of static and token-animated process models

The first (initial) stage of the "If?" and the "What?" questions in the research program is a control–treatment group experiment with random participant assignment to test the hypotheses concerning comprehension[2]. We had two randomly assigned groups across two major Western European universities, amounting to 229 participants from a business engineering and generalist business administration Master program. In each group, we provided 10 questions. Five of these questions were related to semantically rich models; the other five questions were centered around semantically abstract models. The questions were based on the educators' past summative assessments and abstract models from [12]. The models varied in complexity, ranging from simple to complex.

We based our research on the Distributed cognition theory [23], claiming that the comprehension of the process model information cannot be solely attributed to the (external) resource of the model or the internal (cognitive and emotional) resource of the modeler. As a result of the study, we have found that this research theory was supported by the findings that the modeling expertise of the modeler impacted both the comprehension of and the interactions

[2] The survey with experiment items can be found via the link: https://docs.google.com/document/d/1C-bgVHWlCKFCWWZRKBush6dQEQza9qTW/edit?usp=share_link&ouid=111618996847887367021&rtpof=true&sd=true. Static models and animated videos can be accessed in the following Google Drive folder: https://drive.google.com/drive/folders/11_bA_E3qEgk_HVYYO4KYQdJiUzT2YiGv?usp=share_link.

with the models (despite a limited simulation environment that [12] call a ’low-interactivity tool’).

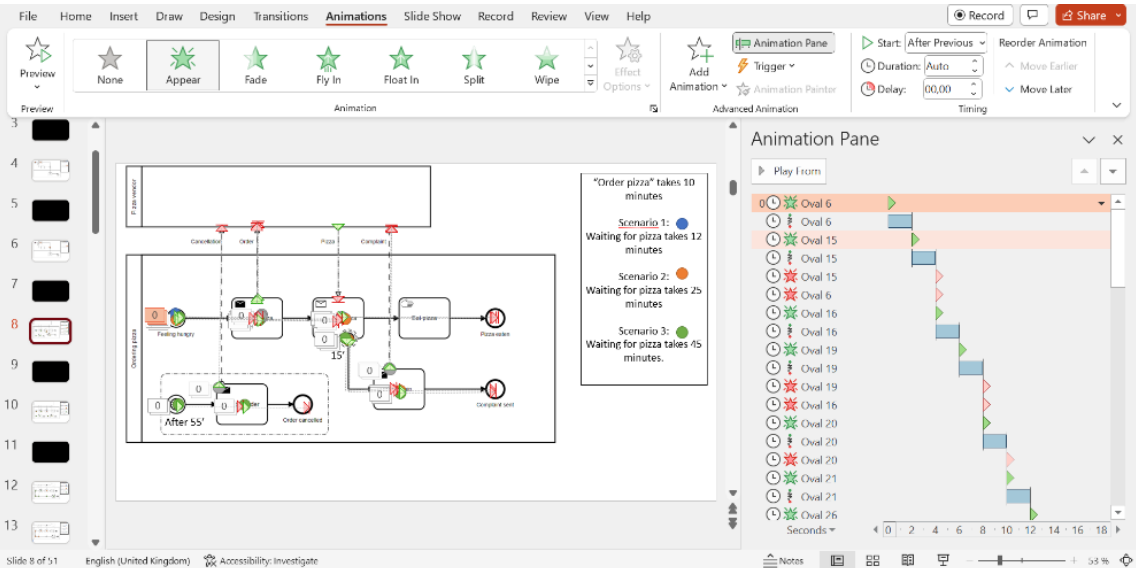

Figure 1: Modeling environment to model TBPM in MS PowerPoint via animations

Given the lack of tools, we used MS PowerPoint to develop a "prototype" of an extended BPMN 2.0 notation. Initially appearing rudimentary, these models eventually proved visually effective, offering sufficient animated representations that benefited novice modelers. We present the "modeling environment" in MS PowerPoint in Figure 1. This ad hoc conceptual modeling approach eliminates the requirement of developing a dedicated application and may even be sufficient for teaching and explanatory purposes. An example of one of the TBPM models is in Figure 2.

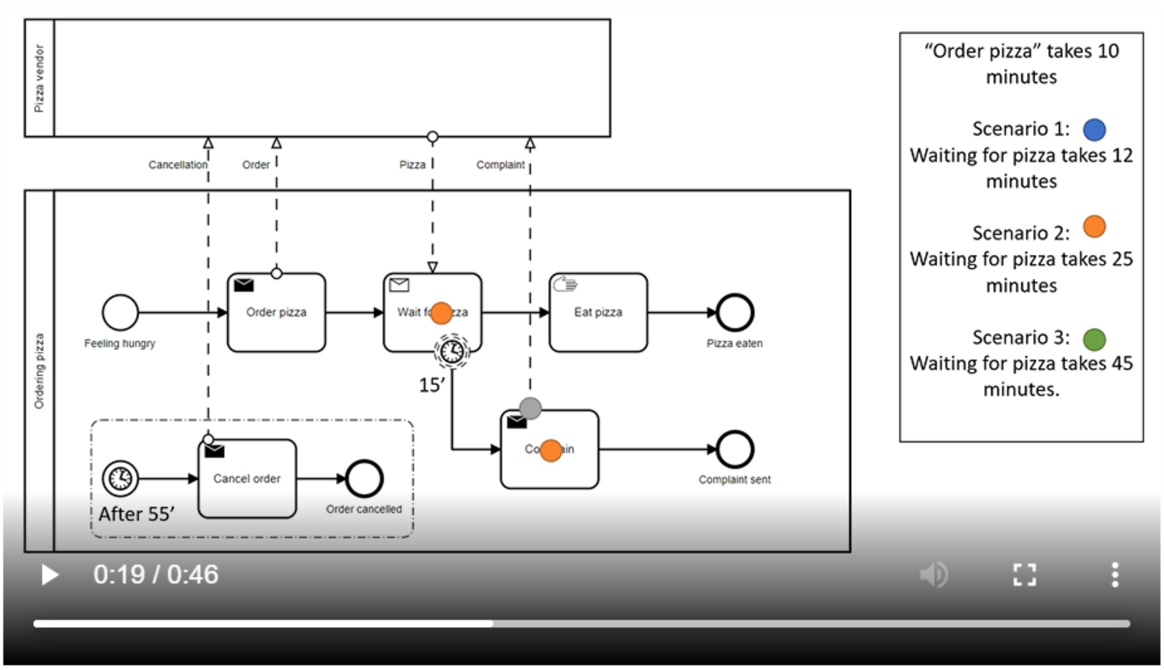

Figure 2: Example of a token-animated semantically rich and average in complexity process model as recorded in a video (screenshot as perceived by the participants in the online survey, with the available model interaction features)

2.2. Technology acceptance of TBPM for learning BPMN 2.0

After we observed a significant positive effect of TBPM on comprehension, we aimed to explore the How? behind the TBPM. During the first experiment, we collected data on the acceptance of the TBPM videos using an extended Technology Acceptance Model (TAM) [24]–[26], which is still a widespread approach to studying the effect of e-learning technologies (e.g., [27]). PLS-SEM was applied to assess the model [28]. The majority of the TAM hypotheses were confirmed, and to gain a more comprehensive insight, we supplemented the results with qualitative feedback from the students, following a suggested mixed methods approach [29], [30]. The summary of the results is presented in Table 2. Primarily, we want to stress that TBPM should be regarded with advantages and disadvantages, often in the context of "smart" use by the educator. Affective and cognitive facilitation is essential for promoting good learning outcomes. The results of this stage are crucial for Stage 4.

Table 2
TAM constructs, PLS-SEM results, and the qualitative analysis summary interpretation of the results

TAM construct	PLS-SEM Model	Qualitative Analysis Summary
Perceived Ease of Use (PEOU)	Impacts LO, PU, PAPM	Instances were easy to follow and understand. They reduced the complexity of the models and questions. The learning process was accelerated with tokens.
Learning Opportunities (LO)	Impacts PAPM	Generally, TBPM was named a learning-facilitation tool, although with minority expressed some criticism. TBPM teaching was suggested to make learning PM easier, faster, clearer, and better. With teacher guidance, TBPM can help explain BPMN models, elements, and patterns.
Perceived Enjoyment (PENJ)	Impacts LO, PAPM, PU	Affective (primarily emotional) aspects should be recognized (e.g., trusting or enjoying using TBPM), with some naming TBPM as enjoyable, appealing, entertaining, and motivating to learn and explore BPMN models. However, some degree of frustration was expressed, which was named positive for learning outcomes.
Perceived Usefulness (PU)	Impacts PAPM	Visualization, animation, and simulation led to the *cognitive facilitation* of the modelers. Tokens were named useful, helpful, clearer, and more structured than static models. Tokens were useful at multiple levels of model understanding: BPMN elements, patterns, errors, arbitrary groups of BPMN patterns, scenarios/instances, and whole models (explained further in Stage 4).
Preference for Token-Animated Process Models (PAPM)	*NA*	Overall, students were in favor of using TBPM in the education of PM. However, further careful exploration was suggested, given the potential drawbacks and challenges of TBPM.
Impact of Educational Background (Biz. Administration vs. Biz. Engineering) (HEI)	Impacts LO, PAPM	*NA*

2.3. Identifying visual routine patterns behind interactions with the token-animated process models using eye-tracking

The third stage runs somewhat parallel to the fourth, involving conceptualizing the theory and model that underpins the functioning of TBPM. Such a theoretical framework is instrumental in structuring eye-tracking experiments.

Eye-tracking is a well-known methodology to analyze the eye-gazing patterns of the participants as they shift their gazes on the screen, and it is often used to analyze the usability and the user experience of (educational) software [31], [32]. Several eye-tracking studies in process modeling demonstrate their methodological usefulness in unraveling the cognitive processes underlying process modeling activities.

For example, [32] employed eye-tracking to identify whether the diagram layout and scrolling may impact the understandability of BPMN models. Eye-tracking was also used to obtain some generalized visual patterns of their behavior, as evidenced by heat maps, focus maps, and scan paths of the modelers' eye gazes, which are said to represent the viewer's attention (Figure 3) [33]. Based on our semi-systematic literature review, it seems that eye-tracking in PM comprehension is relatively recent, with most papers being published between 2018 and 2023. As such, we argue that eye-tracking is an in-demand methodology that can help us research the students' thinking processes and the effect of diagram layouts on the visual routines of the modelers.

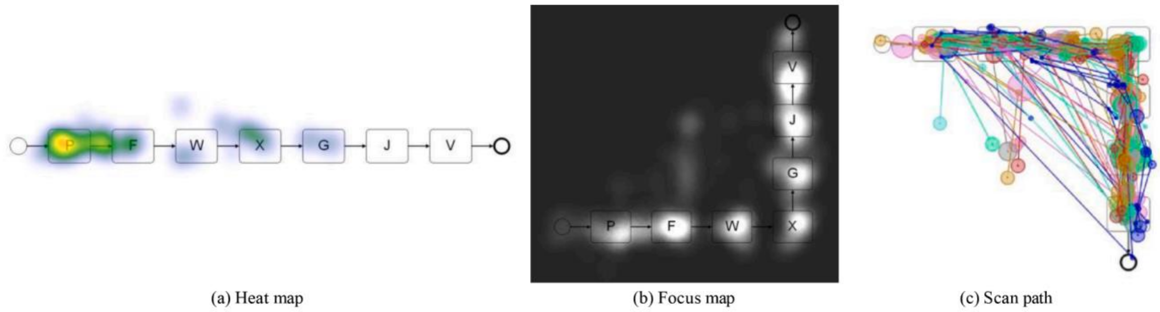

Figure 3: Visual analysis of recorded eye movements showing superimposed (a) heat map; (b) focus map; (c) scan paths over the different mapping of process tasks [33]

To address our ROs in this research program, we have employed previously developed static and animated process models from Stage 1 of the research and adapted them to fit the eye-tracking setting, which meant organizing the layout of the UI elements to fit the eye-tracking system. We also developed an additional BPMN model, which arguably included several potential usage patterns of the TBPM, such as comparing different token scenarios and identifying BPMN (error) patterns. We adapted the questions to the proposed theoretical framework in stage four below. Seven business students (novice and semi-experienced) participated in the first experiment, followed by an in-depth interview (also based on the theoretical framework from stage 4).

Figure 4 represents the suggested framework of our eye-tracking research design. We posit that a BPMN model is an abstraction of a business process, which is instantiated with an additional (overlay) animation via using tokens (a case of a business process). These tokens trigger the individual modeler's eye-gazing paths. All individual modelers' eye-gazing paths can be combined. A generic visual routine pattern is an abstraction of these recorded eye-gazing data. Consequently, TBPM principles can be developed by interpreting an analysis of the generic visual routine patterns. These principles can then inform the design of a BPMN model and tokens (i.e., the instances of business processes) to improve and manage novice modelers' comprehension and learning.

The framework will be applied to both static and token-animated models. We intend to visually and statistically analyze eye-gazing data (e.g., comparing the statistical measures of the time a modeler was looking at a certain BPMN element in a static vs. animated model). We also combine the analysis with the interpretation obtained from the respondents' comments and answers during the interview. These questions are targeted towards their emotional and cognitive states, the difficulties of the models and animation, and so on.

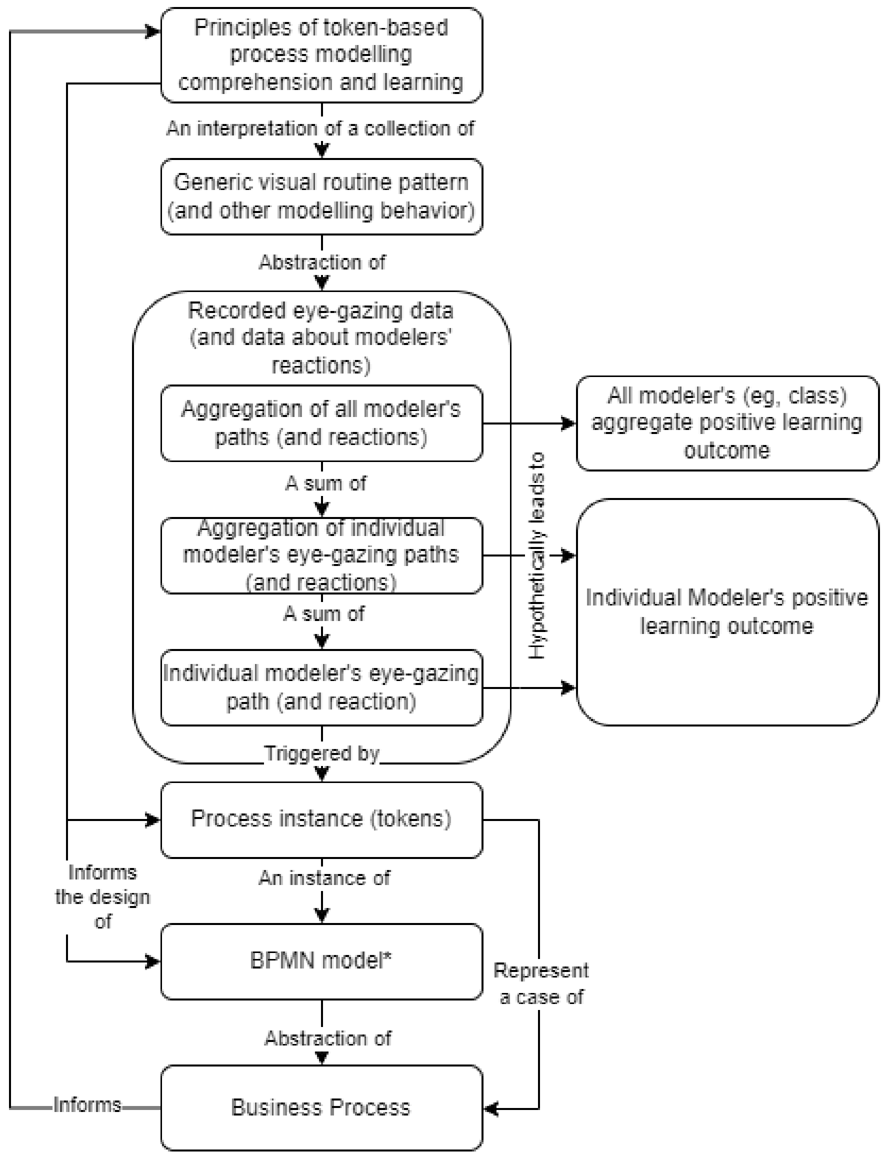

Figure 4: Theoretical framework of abstracting analyses in the eye-tracking research[3]

So far, our first results confirm that TBPM brings greater student comprehension. We also identify interesting differences in the eye-gazing patterns. Figure 5 shows two eye-gazing pictures (of the "generic visual routine pattern" mentioned in the figure above) of a static version and a token-animated version of a process model. In it, we already can observe some patterns: (1) the TBPM is used to verify the answers (as there is an apparent lack of focus on the scenario section and a greater focus on "counting" the number of times a token passes through H, the focus of the question); (2) in the static version, the student explores the model first, which is also read from "right" to "left" (which can imply "reverse engineering" in finding the answer, similar to how one would solve the labyrinth riddle from the exit, and not the entrance) and (3) the student explores different areas in the TBPM. In this first experiment, the static version was always given first, thus implying that the animated version is more suitable for verifying the answers. In future research, the relative importance of both types of models deserves further scrutiny.

[3] Please note that a BPMN model can share different qualities and combine multiple BPMN elements (e.g., gateways, events) and patterns, implying varying process instances and triggered eye-gazing paths.

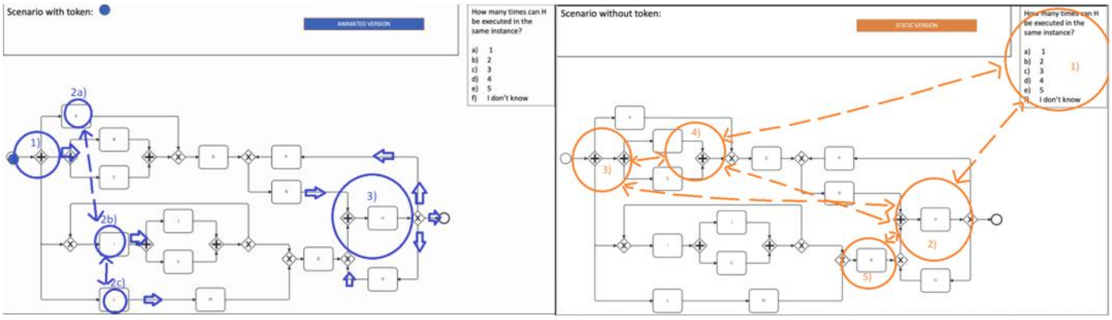

Figure 5: Generic visual routine pattern, as abstracted from the recorded eye gazing data for token-animated (left) and static (right) BPMN process models[4]

While using TBPM for education, the importance of static models for learning purposes should not be neglected since they are less revealing and potentially more challenging, leading to greater learning effects. This was confirmed by some students, stating that animated models can be used complementary to validate their understanding of more complex static models and explain their errors.

2.4. Theoretical insights on the use of TBPM in an educational setting

Based on the literature and the findings so far we present in Figures 6 and 7 our tentative conceptualizations of the TBPM approach to describe the potential function of tokens in teaching PM. In Figure 5 we present several layers of abstraction above the actual BPMN model (consisting of combined BPMN elements). While individual elements can have a semantic meaning (e.g., a gateway represents a decision point), their combination can have a semantic meaning at a higher level of abstraction (such as the representation of a deadline in a business model or modeling exceptions to a regular flow). We call such combinations 'BPMN patterns'. A deadlock is a pattern that is not normally outlined but can be implicitly present in a model. The student can potentially identify this deadlock, but s/he needs to be aware of the possibility of a deadlock first. One of the approaches for the educator is to show and explain the deadlock to the student, for instance, using simulated process tokens. Thus, tokens then serve as a scaffolding mechanism to train students to abstract from the syntactical layer to higher levels of abstraction to identify a collection of BPMN elements as a certain pattern they might otherwise not be aware of. We furthermore argue that by understanding multiple BPMN patterns, a student can more easily grasp the heuristics of process modeling (such as those proposed by 7PMG [34]).

Despite the "nudging" of the viewers' attention, they retain the freedom to choose whether or not to follow or use the tokens. There is also no assurance that their cognitive resources, which can depend on past education, experience, intelligence, working memory capacity, state of mind, or emotional state, will be sufficient to comprehend the model entirely. Thus, the effectiveness of TBPM is contingent on the synergy between an intelligently designed process model and the specific characteristics of the modeler.

Within TBPM, the educator takes on the role of a designer responsible for crafting process models and their animations in a way that enhances the student's comprehension of process modeling rules and methods. This integration of TBPM into the educator's instructional design toolkit highlights the relevance of modern theories in instructional design [35] and the theory of affordance [36].

[4] Please note that numbered circles represent the area of interest where the modeler looks; dotted arrows show the connection between the two areas of interest in a flow between the two; solid arrows show the direction of the modeler's eye gaze.

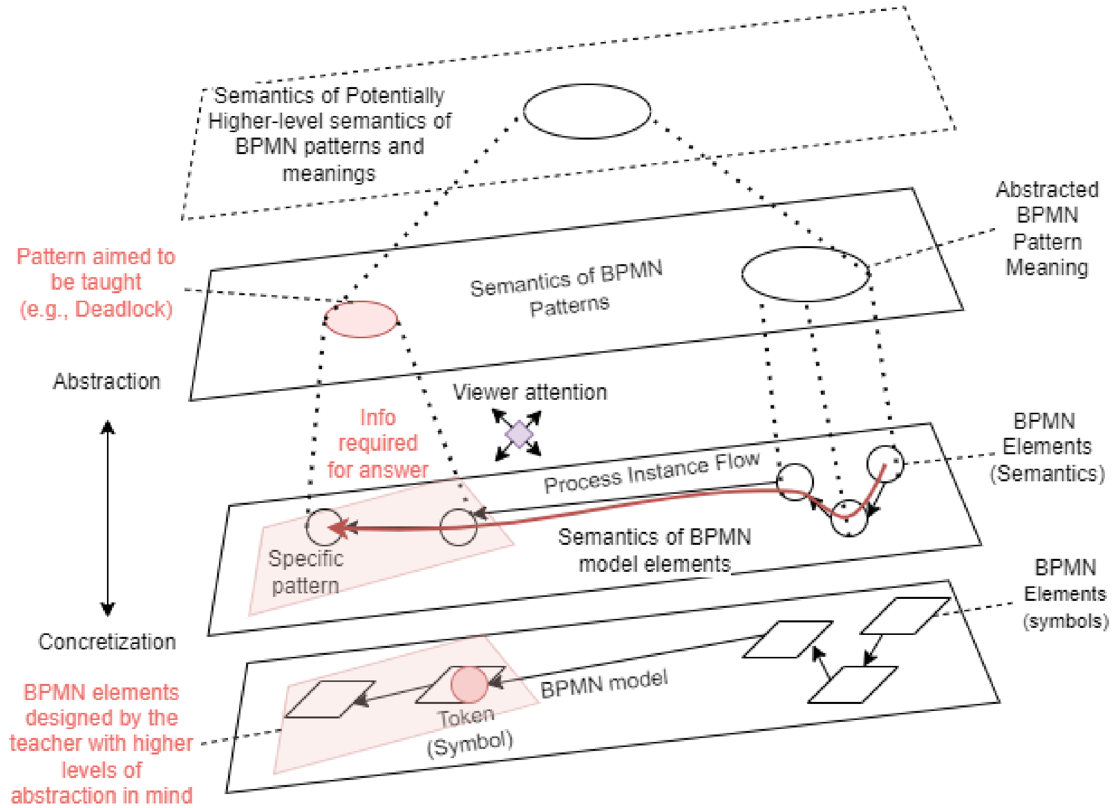

Figure 6: Suggested early conceptualization of how the animated tokens may direct the novice modeler's attention to help abstract to higher levels

In Figure 7, we offer an encompassing framework for further research on TBPM. We base our framework on the Distributed Cognition theory [23] introduced in stage 1 of our research (see section 2.1.). We also incorporate findings from the qualitative analysis, uses, and teaching suggestions in stages 2 and 3, as well as results from the literature on visualization, animation, and simulation features of tokens [5], [10], [12], [13]. From the in-depth analysis of the qualitative feedback of stage 2, and in line with Figure 6, we find that tokens can be used in different ways (different types of interactions), allowing either to abstract away or to concretize towards specific elements (concretizing or abstracting), which we call a "vector of thinking." Different uses may exhibit differing levels of model comprehension, which remain to be explored and studied.

Finally, we recognize several cognitive and affective individual factors, such as improved concentration, enhanced enjoyment, and increased motivation attributed to using tokens, which could influence the learning outcomes.

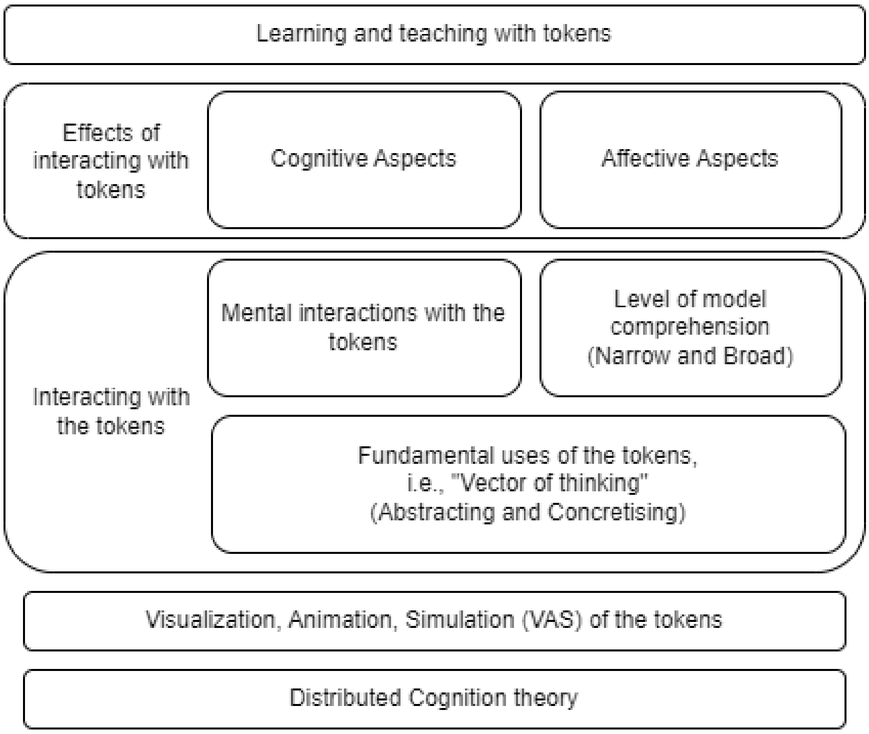

Figure 7: Preliminary proposed theoretical framework of employing TBPM for educational purposes

3. Conclusions and future research avenues

This paper's primary contribution is highlighting the usefulness of token-based animations in education and proposing a theoretical and pragmatic framework of TBPM that can be verified and used in future studies. The framework is grounded in empirical findings and existing literature and can be further extended and refined in future research. The end goal of the research program is to develop theory-based and practically applicable TBPM educational approaches, which can be employed by educators and instructional designers using the BPMN 2.0 formalism, with the potential to transfer the findings to other types of modeling languages (such as Petri nets or UML-Activity Diagrams). Such research is beneficial in the context of a growing interest of the broader research community in domain-specific modeling languages [37] and agile modeling methods engineering approaches [22]. Our future research agenda can proceed in two related research directions: technical- or design-oriented and education-oriented.

The first research objective of the proposed agenda necessitates investigating or further developing interactive modeling tools capable of supporting complex animations within the BPMN 2.0 formalism. As far as we know, existing tools still lack extensive animation and simulation features to depict the behavior of more advanced BPMN elements and patterns or to enable the creation and validation of multiple scenarios. While we are focusing on educational goals, TBPM tools can have broader audiences, such as professional environments. To this end, we also suggest developing a meta-model of the additional notation elements, given the lack thereof.

The second research objective revolves around validating and exploring the educational applications of TBPM. Several more specific research avenues are possible in this domain. We have evidence that TBPM improves comprehension, but it remains uncertain whether this directly translates to a sustained learning effect on the BPMN notation and process modeling principles. As a result, a pivotal research goal is to delve into the longer-term learning effects, thereby considering the identified positive emotional impacts that TBPM can have, such as increased curiosity, heightened focus, motivation to explore process models and elevated trust. Other research directions relate to the possibilities of utilizing TBPM as a scaffolding tool in formative assessments, offering (automatic) feedback to students, and enhancing collaborative modeling, which is typically applied in industry settings (see [38]).

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