Towards Empirically Validated Process Modelling Education Using a BPMN Formalism

Ilia Maslov(✉)

LIRIS Department, KU Leuven, 1000 Brussels, Belgium
ilia.maslov@kuleuven.be

Abstract. "A picture is worth more than a thousand words" may be said of process models, using the words of business and IT leaders. Business Process Model and Notation (BPMN) is a de facto standard used for business process modelling that helps flexible and responsive understanding, analysis and communication of business processes and inter-organisational collaborations. Despite the importance, there are significant gaps in providing empirically justified and systematic pedagogy in teaching process modelling. The research seeks to cover the gap through the systematic literature review of the broader area of conceptual modelling, analysis of novice modellers' common errors and patterns, design of learning goals and course design of process modelling and validating the result using experiments.

Keywords: Business process modelling · Process modelling education · BPMN · Course design · Formative assessment · e-learning

1 Context and Motivation

Conceptual modelling (thereon, CM for short) is the process and discipline of describing aspects of the physical and social world via simplifying it through abstraction and conceptualisation for understanding, communication and managing complexity (Mylopoulos 1992; Buchmann et al. 2019). CM is broad and is used in areas such as software engineering and business process management, and there are particular idiosyncratic differences (Guarino et al. 2020). For example, there are many modelling languages used for different purposes in enterprise modelling – an activity used to capture, represent and capitalise basic facts and knowledge about an enterprise(s) how it's structured, organised and operated. It's contrary to, say, IS modelling, where the purpose is to model an IS, its functionalities, implementation and so on. BPMN (Business Process Model and Notation) is a de facto industry standard for process modelling (thereon, PM for short; Vernadat 2002; Linden and Proper 2014). PM is used to support strategic and operational tasks in organisations, bridge the communication gaps between business and IT and facilitate the engineering of information systems. Hence, it is essential to deliver effective teaching of PM to business students (Dumas et al. 2018). Proficient PM requires the translation of verbal descriptions and non-explicit requirements into formal and visual diagrams of conceptual models and coping with ambiguity, versatility, open-ended problems, making it a challenging activity for novices and experts alike (Claes

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et al. 2017). To this task, usually, the pedagogy is not systematised, primarily based on the teacher's personal experience, while also imbalanced in terms of different levels of remembering, understanding and applying the knowledge, with the eminent gaps in scaffolding and overall evaluation of student's knowledge, leading to a wide diversity of pedagogy methods (Bogdanova and Snoeck 2017 and 2018a). Moreover, even though the quality of process models may impact the outcome of business processes and high demand is placed on the high-quality process models, the general quality of such models is low in many cases. Assisting in training modellers may help improve process modelling skills and subsequent process models (Claes et al. 2017). Furthermore, despite the extant quality frameworks and studies about process model quality, which also focus more on the syntactical rather than semantic quality metrics, there are currently no concrete frameworks applicable to effective teaching of process modelling (de Oca et al. 2015; Claes et al. 2017; De Meyer and Claes 2018). Out of 87 studies analysed by Avila et al. (2020), only a third provide empirical evidence for process modelling guidelines, warranting consistent definitions, empirical evidence and feedback about guidelines to modellers. Given all that, researchers in CM and PM education call for better, more systematic and effective approaches to deliver such education. It is also suggested that CM education may not always corroborate between fields of application, e.g., process modelling and IS modelling (Buchmann et al. 2019; Rosenthal et al. 2019). This research project will seek to systematically analyse findings from the CM education and apply them in grounding research on PM education, as the latter is conceived partially as a type of the former in the literature. The project will also seek to establish process quality frameworks, which are specific to teaching PM. Optimal learning objectives and course design qualities shall be designed using the framework, which are then to be validated through the use of experiments and assignments, hence aiming towards promoting scientifically rigorous theory within PM education discipline. Consequently, the sections will introduce state of the art, research objectives and planned research methodology to attain the objectives.

2 State of the Art

In this section, I shall briefly review the concepts relevant to the research project and state of the art literature discussions. Figure 1 below summarises the research framework of concepts and relationships relevant to the project. It is based on the preliminary results from a systematic literature review and helps frame the research, even though it is still work-in-progress and may not be considered as very precise, with further potential to rethink the proposed conceptualization and abstraction of phenomena. Due to the space limitations, the framework description will be briefly sketched using the evidence examples from the literature, primarily via the explanation of *Relationships* (***R***) between *Concepts* (***C***), which are numerically referenced.

There are multiple individual factors (***C1***) that have an impact on the learning outcomes and constitute an important theme of learner differences (***R10***) (Lim and Morris 2009). For example, the learner's working memory's two functions (holding and processing of information and ability to build new relations between elements) were found to influence the process and hence, the model quality (***R1, R6***) (Martini et al. 2016).

Intelligence is strongly correlated to the ability of individuals to learn and apply new information and the structuredness and self-directedness of learning (***R2***) (Gottfredson 1997). The cognitive styles of people correlate with the way process models are constructed (***R1***) (Figl and Recker 2016). Personality and intrinsic students' motivation to learn are very reliable and highly important in determining the learning outcome and how a student learns (***R2***, ***R10***) (Zhou 2015). Academic discipline may affect how students view the process of CM and understand the course content through their discipline lens (***R1, R2***) (Buchmann et al. 2019). Educators are suggested to target individual learners' motivation by suggesting learning application or how useful it would be to the learners in the future. It is also recommended to match students' knowledge level, learning needs, cognitive style to the learning difficulty and variation in delivering instructions, hence promoting (at least partially) individually personalized course design (***R2***, ***R5***) (Lim and Morris 2009; Cope and Kalantzis 2016).

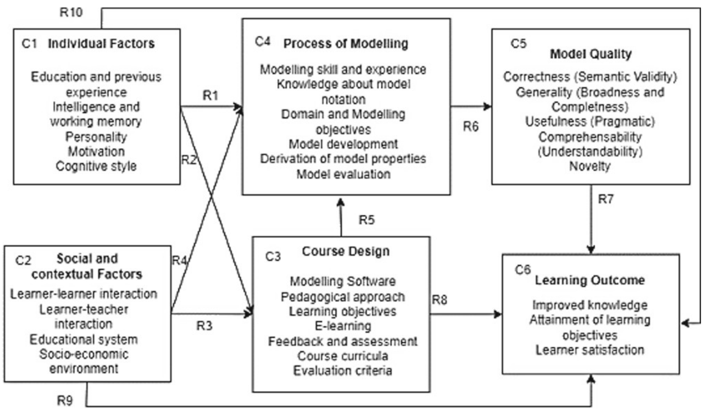

Fig. 1. Proposed (work-in-progress) research framework.

In addition, there are relevant social and other contextual factors (***C2***). Even though individual factors better predict motivation to study and learning outcomes, social factors were found more frequent. Social factors can be conceptualised as social punishment avoidance, social expectations by parents and teachers, material rewards and social privileges. Hence, both the classroom social environment and broader socio-economic environment significantly impact learning outcomes and are suggested to keep in mind when viewing the educational system at large (***R3***, ***R9***) (Marić and Sakač 2014). Per se, collaborative CM in higher education may facilitate learning outcomes, mediate the interaction between individual and social factors, and promote transformation and reflection between various forms of knowledge (***R4***, ***R6***) (Kosonen et al. 2010). In collaborative PM within corporate settings, modellers may adapt their modelling style, with stronger modellers being able to create both concrete and abstract models and focus more on the comprehensibility of the models. In contrast, weaker modellers can create only concrete models (***R4***, ***R6***) (Wilmont 2020).

Recent research indicates the potential to adapt course design (***C3***) to deliver more effective training of PM skills and achieve better learning outcomes (***C6***). Buchmann et al. (2019) viewed the course design of teaching CM as a design problem and using workshops while bearing in mind students' individual factors (***R3***, ***R4***). Claes et al.

(2017) have developed a method that adapts to the student's cognitive profile and trains with the most fitting approach to model (***R2***, ***R5, R8***). Bogdanova and Snoeck (2018b) trained students' CM through a Massive Open Online Course's formative assessment using a learning ontology that connects learning items, learning objectives and errors, and such feedback is well-received by the students (***R3***, ***R5, R8***). Sanchez-Ferreres et al. (2020) developed an automated software, which allowed to make BPMN models and automatically provide immediate feedback about quality issues in the model (***R5, R8***). Software systems overall play an important part both in training and in future work related to process modelling (***R5***, ***R8***) (Dumas et al. 2018), as part of an e-learning trend, which is using ICT to deliver information in training and education, often in the blended learning context (***R5***, ***R6***) (e.g., Lim and Morris 2009).

There are several frameworks to evaluate conceptual models' qualities and guidelines to follow during process modelling to improve the quality (***C4*** and ***C5***). Process model quality frameworks (***C4***) may include 3QM (Lindland et al. 1994), Guidelines of Modelling (Uthmann and Becker 1999), a taxonomy of quality components (Thalheim 2010). The qualities of conceptual models may be used to evaluate the errors made during the teaching and learning process by the novice modellers (***R6***, ***R7***) (Bogdanova and Snoeck 2018). There are also PM guidelines used to improve the process of PM and novice modellers' skills (***R5***, ***R6***), e.g., 7PMG is a set of seven process modelling heuristic guidelines (Mendling et al. 2010). There are currently no directly applicable process model quality frameworks and guidelines in the context of teaching novice modellers' because the existing ones are too abstract to apply in the educational context (***R7, R8***) (de Oca et al. 2015; De Meyer and Claes 2018; Avila et al. 2020).

3 Research Objectives and Methodology

The PhD research will be conducted for four years. In this work, the ultimate goal is to create empirically validated learning goals, course design and modelling proficiency assessment methods to provide effective and systematic PM education, thus extending the theory of PM education. Since BPMN is an industry-standard and used by companies (in and outside the IT sector), teaching BPMN and quantifying modelling quality and modellers' proficiency is thus also relevant for training programs within organisations. Hence, the research project leans towards a pragmatic research philosophy and research design methodology (e.g., Buchmann et al. 2019). The research stages within a research design methodology may have to be iterative, following the four research objectives as roughly the four stages: (1) to explore the problem, (2) to analyse the problem, (3) to design the solution, (4) to validate the solution. The research will promote reproducible research via research data management plans making collected data available online on free repositories and following other ethical research guidelines (Arnold et al. 2019). The research project will seek to achieve the research objectives (ROs) via the following approaches and methodologies:

RO1. *To explore the state of the art in the literature of teaching methods and student behaviour in the field of conceptual and process modelling.*

RO1 is to give research context to the PhD project, and will mainly be achieved by answering the **RQ**: "*How can the research findings from CM education help to extend the* *research of process modelling education?"* Given the early literature review findings, there are some significant gaps in connecting research theories of CM education to PM education, which may differ concerning educational context, students' background, intended use, etc. Covering the research gap can help promote the understanding of PM education based on the findings in CM education. On this basis, the first paper is currently in progress, aiming to answer RQ1. The review is based on the bibliometric methods (e.g., see Zupic and Čater 2015) of analysing bibliographical data of 2000–2021 years with the help of statistical methods, which is an uptrending technique facilitated by the availability of powerful software and hardware. Bibliometrics promote research replicability and facilitate easy analysis of the broader field of research through literature analysis. If combined with qualitative content analysis, it further promotes in-depth analysis of emerging themes and research topics. At later stages, the research will continue to explore literature at need.

RO2. *To analyse students' novice modeller's behaviour of process modelling, using a dataset of BPMN models, focusing on typical types of errors (patterns).*

RO2 does raise an important **RQ**: "*Can we find error patterns and types that typically reflect novice modeller's behavior and expose novices's miscomprehension of PM in particular?"* Analysis of modeller's behaviour will primarily deal with produced process models and qualities (***C5***). The research project will deal with a previously collected extensive dataset of students' BPMN models. The dataset contains over 1000 BPMN models already. Data is collected from three campuses, three different teachers, and three different programs across two universities in Belgium. Each academic year new data can be added. Attaining RO2 will involve assessing the models via qualitative manual analysis and potentially quantitative software-facilitated analysis. In such a way, an empirically evidenced taxonomy of common novice modellers' errors could be constructed, like in Bogdanova and Snoeck (2018a). However, feedback and review from the course teachers will be required. Such a qualitative approach to systematisation of empirically-based taxonomies and categories is an inductive approach, which allows building a theory of common errors in the learning of PM ground-up, which can later be used for course design and be tested in experiments. The approach also follows the ideas of the past research (e.g., 3QM) but aims to extend existing taxonomies with more semantical metrics and guidelines. The analysis could be combined with the research of process patterns (Fellmann et al. 2018), but in the context of education. The analysis may be done also at the modelling process level (***C4***). For example, using eye-tracking data from the way students interact with the process models could give insights into cognitive styles of process modelling (Tallon et al. 2019). This can help move towards a broader theory of PM education, with early attempts at hypothesizing different concepts and relationships shown in Fig. 1.

RO3. *To design and validate pedagogical approaches and theories (process pattern learning, a taxonomy of errors, formative testing and (semi-)automated feedback) for PM, through experiments, surveys, interviews and (formative) test results.*

The final RO raises an important, pragmatically valuable **RQ**: "*What scientifically rigorous pedagogical approaches are most effective to training process modelling, and among novice modellers in particular?"* Designing systematic learning goals and course content (***C3*** and ***C6***) of PM education may be accomplished using design methodology (Buchmann et al. 2019). Within the research scope of this project, there already exist some pedagogical solutions, suggesting some course design (e.g., see Bogdanova and Snoeck 2018a). Past literature has already tried to analyse these solutions based on the classical learning philosophies: behaviourism, constructivism, cognitivism (e.g., see Rosenthal 2019). This research project will seek to extend the existing literature, developing PM-specific learning goals and course design. Notably, Cope and Kalantzis (2016) have suggested moving the pedagogy from the traditional teacher-led, didactic pedagogy towards more reflexive pedagogy, which is an adapted pedagogy with effective use of digital media, not just the traditional pedagogy done over the Internet. They suggested using seven affordances provided by the new e-learning technologies, including recursive feedback throughout the learning, multimodal meaning of knowledge, active knowledge-making by the students, collaborative learning, and personalised learning. This theoretical framework may provide invaluable guidelines to frame the design methodology. Furthermore, designing an adapted Bloom's learning framework, like Bogdanova and Snoeck (2019a), can help arrive at appropriate learning goals and outcomes in education. For example, previously established error taxonomies and patterns in the educational context can further improve PM pedagogy (Bogdanova and Snoeck 2018a). Only recently, researchers started to systematise patterns of processes (Fellmann et al. 2018), which is a potential to research the yet underexplored field of pattern-based learning of process models. Designing and utilising formative assessment IT systems can help with personalized teaching of CM in different areas, and in particular in PM, even though it is still an underexplored topic of research (Claes et al. 2017; Bogdanova and Snoeck 2018b; Bogdanova and Snoeck 2019b; Sanchez-Ferreres et al. 2020). The potential is to replicate and extend the experiment in Bogdanova and Snoeck (2018b), as they have constructed a MOOC and suggested improving the learning outcomes via formative assessment in the course design methodology. IT and software are thus an essential theme in the research project as a critical component. ICT is the main mode through which conceptual models of all types are generally created in academia and the workplace and ICT facilitate learning under an emerging e-learning paradigm.

Conducting experiments in the learning context is one of the most popular approaches to validate learning goals and course design hypotheses. It is empirically evidenced, and there is a lack of empirical studies in the research topic area (Avila et al. 2020). The primary goal of the RO3 is to validate the hypotheses concerning the implementation of the improved pedagogical approach (***C3, C4*** and ***C6***). There are multiple ways to validate the hypotheses through the experiments. Experiments could be based around specific cognitive tasks involving certain experiment conditions with learning outcomes as outcome variables while controlling for independent variables (Martini et al. 2016). For example, Claes et al. (2017) suggested analysing the two student groups with and without new method implementation to teach process modelling before and after administration, showing potential for their method. RO4 will seek to validate the designed course instructions. Another approach to validation is to scrutinise learning outcomes and monitor their evolution. Equally, student's learning progress can be analysed through formative assessment and continuous feedback.

4 Conclusions and Future Work

The topic of process modelling education is a complex phenomenon, drawing on knowledge from different disciplines. The research project has a pragmatic orientation, with the ultimate goal of moving towards an empirically validated effective PM education pedagogical framework. To this objective, a research design methodology is a practical approach. Within this methodology, there will be an emphasis on getting empirical data and validating the hypotheses using experiments. The project has been focused on RO1 with the ongoing SLR insofar. The required data is available for RO2, and for RO3, there are valuable frameworks to be used to design appropriated learning goals and contents, such as ideas suggested by Cope and Kalantzis (2016) or Bogdanova and Snoeck (2019a). RO2 and RO3 will be achieved in parallel and iteratively. Several potential approaches have been discussed, such as an experiment to analyse the impact of real-time process model simulation on learning outcomes.

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