Design and Evaluation of a Web-based Modeling Platform to Support the Learning of Conceptual Modeling and of Studying the Corresponding Learning Processes

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Abstract: The research presented in this dissertation proposal aims at designing, developing, evaluating and studying a web-based modeling platform to support the learning of conceptual modeling and of studying the corresponding learning processes. More specifically, this research project is situated in a distance learning and teaching context and pursues the primary objective of creating a learning and teaching software for guiding and supporting the learning of conceptual modeling and of providing the instructor with means to observe individual and aggregate learning processes. Learner interaction with graphical model editors is tracked and analytics allow for insights at the individual and aggregate learner levels.

Keywords: Construction-oriented research, learning conceptual modeling, learning process of conceptual modeling, teaching conceptual modeling

1 Motivation, Background, and Objectives

Conceptual modeling as an activity involves a complex web of cognitive performances and human actions including communicating, interpreting, abstracting, conceptualizing, visualizing and justifying. Despite its proliferation in practice and its history in scientific research spanning more than four decades, the *learning process of conceptual modeling* has received only limited attention so far. Further knowledge about the learning process of conceptual modeling—from the beginning modeler to the intermediate to the advanced modeler—promises to assist in shaping learning support, e.g. in modeling tools, as well as in shaping teaching didactics, e.g. in focussing on typical learning difficulties.

The present dissertation project is part of a long-term research program to study learning of conceptual modeling, and is situated in a distance learning and teaching context involving introductory courses on conceptual modeling with large cohorts (up to 1,500 students). Primary objective of this dissertation project is to develop a user-friendly, intuitive and robust browser-based modeling application, which allows for tracking modeler interactions to obtain a more comprehensive understanding of how beginning modelers learn. The proposal

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at hand reports on the current state of the dissertation project and, in particular, details related work, outlines the current development stage of the web platform and describes intended next steps in the research process.

2 Research Approach

The dissertation project follows a construction-oriented research method with a research configuration tailored to the research artifact and cognitive interest [Fr06]. The main knowledge contribution of this dissertation project is comprised of a software artifact, i.e. the web-based modeling platform which features a novel approach to track the learning of beginning modelers and for identifying and analyzing patterns of learning processes based on tracking data. Selected steps of the research process include (1) critical analysis of the literature to derive a set of requirements towards the artifact; (2) the design of the software artifact, and (3) its evaluation in an initial experimental setting. To achieve these objectives, a literature review is presently underway that addresses the theoretical foundations including theories of language acquisition, learning and teaching conceptual modeling, improving the process of process modeling, among others. In parallel, a prototypical implementation of the web-based modeling platform has been developed including first approaches tracking user interactions and analyzing tracking data.

3 Related Work

Early contributions to the discussion of improving the process of process modeling, e.g. [PZW10, Pi14], considered to develop a modeling environment for the analysis of the process of process modeling with a tool, named Cheetah Experimental Platform (CEP). CEP is designed to support the workflow of controlled experiments—each step in the experimental workflow uses components provided by CEP [PZW10, p. 15]. The Cheetah Modeler, which is a part of CEP, enables the investigation of how process models are constructed [PZW10, p. 16]. It further offers different analysis functionalities, e.g. Cheetah Analyzer, which can record the process of creating process models with Cheetah Modeler [PZW10, p. 17] and replay them with the integrated step-by-step execution. However, while the step-by-step execution is a suitable approach to reconstruct the process of process modeling, important thoughts and cognitive performances cannot be tracked, e.g. when creating synchronizations/parallelizations. Another experimental environment to analyze modeling behavior is JMermaid, see [SSD14]. This tool is very related to the presented dissertation project and is based on a process mining analysis of conceptual modeling behavior of novices. The authors focus on improving teaching practices in the field of conceptual modeling by investigating the perspectives of process-oriented feedback. An approach to visualize the generated results is introduced, e.g. [Cl13], allowing for further analysis, e.g. for specific pattern reconstruction. Contrary to this approach, the dissertation focusses on two specific modeling approaches: data modeling with a didactically prepared variant of the Entity-Relationship Model [Ch76] and business process modeling with

MEMO OrgML [Fr11]. The rationale for preferring MEMO as learning language for this dissertation project over Business Process Model and Notation (BPMN), ARIS or comparable methods is based on two considerations: (1) MEMO provides an extensive set of constructs for roles and units; (2) in contrast to other approaches, like ARIS, the language specifications of the MEMO method are freely available and documented in several publications. For future work, it could be significant to investigate the process of creating, for example, organizational structure diagrams or other modeling approaches. In the context of declarative process modeling and understandability, in [Ha13], an empirical investigation is reported, asking subjects in an exploratory study to describe an illustrated process, which was handed out before. Additionally, the authors applied a think-aloud approach and recorded the subjects' actions as audio- and video-files [Ha13, p. 7]. A framework for assessing the perceptual properties of visual notations in software engineering is presented in [Mo09]. A further approach for improving the process of process modeling is to use predefined patterns. In [KR15], a set of Domain Process Patterns (DPP) for improving the process of process modeling is introduced.

Eye tracking is a popular research method in psychology and for gathering information from online web pages. Recording eye movements of participants viewing a web page can reveal information about the page design and its strengths and weaknesses. To improve the insights of the modeler behavior, [Pi13] presented an eye movement tracking analysis. However, eye movement tracking only measures the participants' attention and not which information will be processed—looking at one place does not imply that a modeler recognizes or even processes the information. About concerning the investigation of learning and teaching conceptual modeling with eye movement tracking, biases resulting from different peripherals have to be considered, e.g. the participants could unconsciously move the mouse to any corner without losing their eye fixation points.

Additional related research fields, which have not yet been elaborated, are learning natural languages and learning artificial languages. There might be similarities between learning natural languages and learning artificial languages for conceptual modeling. Different knowledge areas of further work remain unexplored, for example, cognitive science, psychology and, especially the Cognitive Load Theory (CLT) [CS91], which is a widely accepted theory and has been empirically validated in studies so far [Ba02] as well as approaches and guidelines for learning, e.g. [Ki02], are intended to be worked on for the dissertation project in the future. Based on previous research in this field, this project differentiates at obtaining a more detailed understanding of *how* to track modeling beginners by a web-based modeling platform and, also, to achieve more insights in the learning process of modeling beginners. I assume such understanding to be valuable for the design of user interface of modeling tools as well as for more accurate interpretations for implicit feedback to support the learning and teaching process.

4 Status Quo

At present, a prototypical implementation of the web-based modeling platform has been implemented exploring design and implementation strategies for efficient user tracking,

tracking data persistency and analytics. The prototype currently implements graphical editors for a process modeling language MEMO OrgML [Fr11] and a variant of the Entity-Relationship Model. Prior to the prototypical implementation, initial requirements have been defined based on an analysis of literature on the process of process modeling, learning conceptual modeling and tracking approaches as well as on learning visual notations. These requirements are further extended and refined as the prototyping proceeds. Currently, the theoretical background is further explored by further literature analysis with regard to empirical and theoretical findings on learning, teaching, and language acquisition. Subsequently, different tracking approaches will be integrated, such as history event tracking and replay functionalities to gather a large amount of information over the user interaction process with the graphical editors. Corresponding analytics of tracking data will be added with first prototypical implementations already implemented.

5 Next Steps and Challenges

Next steps of the dissertation project include (1) a comprehensive literature review on learning and teaching conceptual modeling and improving the process of process modeling; (2) developing a final version of the web-based modeling platform; (3) implement further functionalities to enrich the tracking of modeler interactions and to achieve insights into learning processes of conceptual modeling. A fundamental assumption of the research is that modelers' learning process can be tracked by observing modelers' interactions with the modeling platform. For the dissertation project, it is an open question at present how to enrich user interactions by additional means, e.g. by history tracking, video recording, thinking out loud and other richer means of observations.

Many directions of further work have not yet been explored in the present dissertation project. One major challenge is *how* to achieve insights into modelers' learning process for more accurate interpretations for implicit feedback on conceptual modeling and *how* to track modelers' interactions in an adequate fashion. Beyond the tracking of user interactions, the influence of relevant other modeling aspects outside of the modeling tool has to be considered. Which of these aspects could be captured how remains open. Achieving the primary objective of this dissertation project implies to incorporate insights from a number of other scientific disciplines, e.g., linguistics, semiotics and philosophy of language, and, hence, suggests transdisciplinary collaboration—which I welcome and seek.

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