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A browser-based modeling tool for studying the learning of conceptual modeling based on a multi-modal data collection approach

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Abstract. How do we learn conceptual modeling? What are common learning difficulties? Which tool support assists learners in what respect? The paper at hand reports on the design and development of a browser-based modeling tool integrated with a learning observatory in support of learning conceptual modeling and of studying the learning of conceptual modeling. Implementing a multi-modal data collection approach, the learning observatory tracks learner-tool interactions, records verbal data from learners and surveys learners about their learning processes to provide for analyses at the individual and aggregate learner levels in the quest for identifying patterns of learning processes, learning barriers and difficulties. We report on the current state of prototype development, discuss its software architecture and outline future development steps.

Keywords: Conceptual modeling, Modeling tool, Modeling tool development, Prototyping.

1 Introduction

Viewed as an activity, conceptual modeling involves an intricate array of cognitive processes and performed actions including abstracting, conceptualizing, associating, contextualizing, interpreting & sense-making, judging & evaluating, drawing & visualizing, and, in group settings, communicating, discussing and agreeing. Learning conceptual modeling is, hence, a complex task for learners associated with codified as well as tacit knowledge and a learning process involving knowledge acquisition through experience (e.g., [1]). Learning conceptual modeling involves mastering theoretical foundations, modeling methods and languages, and applying them to modeling tasks by critically reflecting on domain-specific technical language in the light of set modeling objectives [2, 3].

Research on learning conceptual modeling, hence, seems likely to benefit from taking multiple complementary angles on studying learning processes to account for their multifaceted nature. Related work on learning support tools include process-oriented feedback [4, 5], gamification [6] and serious games [7] as well as work on the collection, aggregation, analysis and evaluation of data on learners and their learning context

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subsumed under the term learning analytics [8, 9]. Complementing prior work on tool development for supporting and studying learning conceptual modeling, we initiated a long-term research program to better understand how novice modelers learn a modeling language respectively modeling method and how tool support assists learners in what respect. The research program is based on the fundamental assumption that learning processes of novice modelers deserve study from several complementary perspectives. Therefore, it bases on mixed method research designs involving multi-modal data collection.

As part of that research program, we have been developing a learning observatory integrated with a modeling tool in support of learning conceptual modeling and of studying the learning of conceptual modeling. Overarching research objective guiding the implementation efforts is to identify patterns of learning processes, common learning barriers and learning difficulties. For that purpose, the learning observatory currently supports three modes of data collection on learners' learning processes: (1) tracking and recording (every) learner-tool interaction; (2) conducting written pre- and post-modeling online surveys of learners; (3) recording verbal data from learners while modeling (supporting 'think-aloud'-like data generation methods [10]).

The primary application context of the modeling tool and learning observatory are two introductory courses on conceptual modeling in a distance learning and teaching setting with large cohorts of students (1000+ and 200+ per semester). Based on a blended learning approach, these two courses presently pick out data modeling (in a variant of the Entity-Relationship Model), object-oriented modeling (a tailored subset of UML Class Diagrams) and business process modeling (a subset of the MEMO OrgML [11]). Development of the modeling tool is, consequently, tailored to the respective taught modeling languages and requirements for software development following from this specific application setting.

2 Prototype Presentation

The current working prototype has been under development since 2013 to explore design and implementation strategies for tracking interactions of learners with graphical editors. Two essential requirements drive the prototype development: (i) Platform independence as well as (ii) usability (especially an intuitive user interface). Technically, we opted for a web application with a JavaScript-driven browser frontend and a Java EE (Enterprise Edition)-based backend (see [12, 13]). The frontend design considerations, operating principles and essential requirements are outlined in [13]. A revised and extended version of the software architecture is depicted in Fig. 1. Note that the frontend user interface currently implements two graphical editors: First, an editor for constructing ER diagrams (in the variant used in the two introductory courses) and a second editor for creating MEMO control-flow and decomposition diagrams [11].

As a first step to realize tool support for learning conceptual modeling in the introductory courses, we have implemented an ad-hoc syntax validation to verify the syntactic correctness of conceptual models. Feedback on syntax errors is provided via natural language comments and the highlighting of graphical notation symbols. Additionally, a video-based step-by-step tutorial comprising short video excerpts has been implemented aimed at accelerating and fostering the general handling of the tool. Moreover, the tutorial provides an open discussion forum for learners to discuss emerging difficulties, e.g., with other learners while working on modeling tasks or to receive technical support on issues and news concerning the tool.

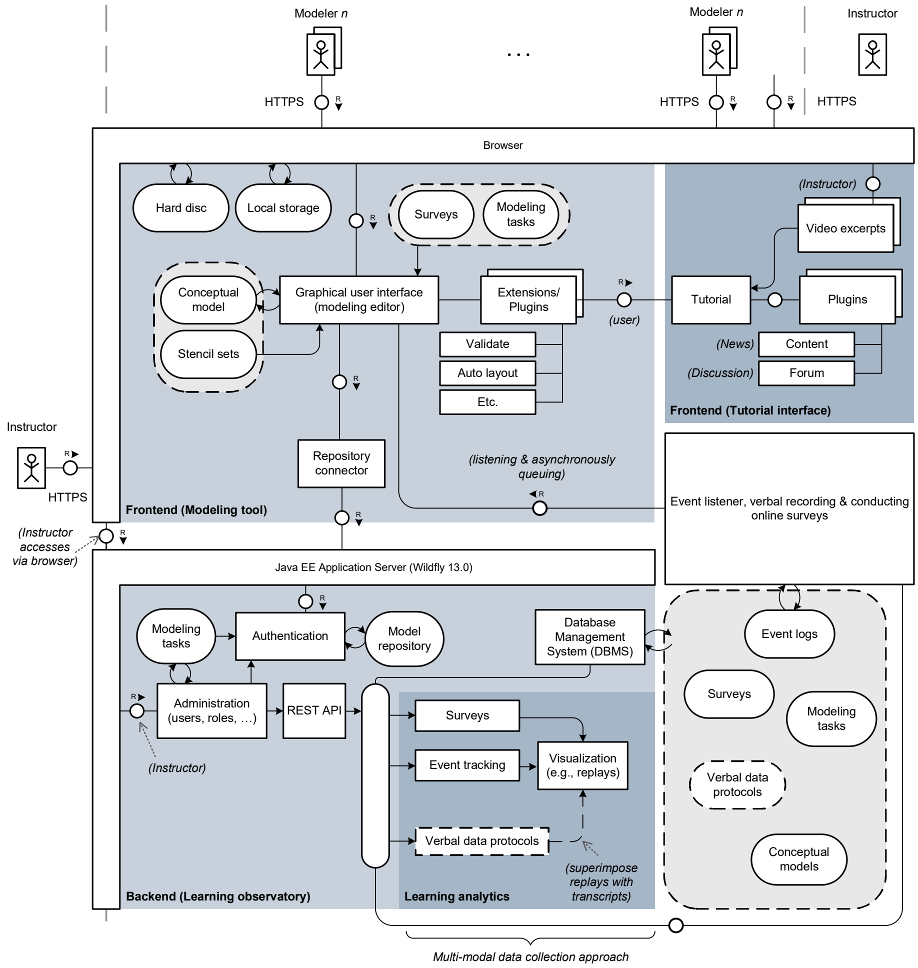

Figure 1. Revised software architecture at the conceptual design level depicted using FMC (Fundamental Modeling Concepts, see [14])

To include several complementary perspectives on learners' learning processes, we extended the learning observatory with further data collection approaches. Particularly, the learning analytics component has been extended for tracking, analyzing and evaluating learner-editor interactions, e.g., algorithms for tracking events. More specifically, the prototype implements an algorithm which tracks the learner-editor interactions, while working on, e.g., modeling tasks, by storing every learner-tool interaction with the graphical editor as a timed discrete event (*modelid, modelElementid, timestamp, userid, operation, type, content*). The tracking data is subsequently used for the learning analytics component. Currently, the learning analytics analysis and visualization component supports a step-by-step replay (i.e., visually showing every step of model construction), an automatic replay (i.e., visually showing model construction in real-time) and – based on prior related work on learning analytics (e.g., [5]) – a text-based console displaying further information about learner-editor interactions, e.g., manual use of the syntax validation.

Beyond these modes of data collection on learners' learning processes, we have implemented a software component to create and to conduct pre- and post-modeling online surveys of learners about their learning processes and demographic data within the modeling tool. Since learner-editor interactions are a rather restricted mode of observation of learning processes, we opted for additionally collecting verbal data by asking learners to think out load while modeling (e.g., [15]). Currently, a further component of the learning observatory is implemented to collect verbal data protocols by recording voice while learners are working on a modeling task. Generally, we view it as an open question whether and how to further enrich researchers' observations on learning processes beyond learner-tool interactions. As learning of conceptual modeling entails an intricate array of cognitive processes and performed actions, studying learners' learning processes suggests applying further complementary data collection approaches including, for instance, eye tracking (e.g., [16]) respectively video recording via webcam (e.g., [17]).

To evaluate the design and implementation, we are currently preparing for a small-scale study aimed at achieving first insights into barriers and difficulties faced in learning conceptual modeling and into learners' learning processes. Involving selected students working on a modeling task in the graphical user interface of the modeling tool, the design of the study utilizes the multi-modal data collection approach combining tracking learner-tool interactions, recording voice from learners and conducting pre- and post-modeling online surveys of learners. Informed by these preliminary insights, a large-scale study will be designed aimed at identifying patterns of learning processes, common learning barriers and learning difficulties.

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