Towards an Automated Assessment of Graphical (Business Process) Modelling Competences: A Research Agenda

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Abstract: In Business Process Management (BPM), graphical process modelling plays an important role because process models can significantly support BPM endeavors in many different ways. Hence, it is also crucial in the context of learning and teaching BPM. Graphical modelling in general is also a curricular core component of higher education in related disciplines such as information systems engineering or software engineering. There are numerous concepts and tools which support learning and teaching of graphical modelling, but most of them have so far been isolated from each other and are used only locally. In order to increase the quality of learning and teaching in modelling courses, it is desirable to better integrate these approaches and identify commonalities. This paper discusses several challenges of integrating learning and teaching approaches for graphical modelling and outlines an approach to a solution that is currently pursued in the ongoing research project KEA-Mod.

Keywords: Business Process Modelling; Modelling education; Educational technology

1 Introduction

Graphical process modelling plays an important role in Business Process Management (BPM) as many different functionalities supporting successful BPM are based on process models. Hence, process modelling is a crucial aspect for the qualification of BPM experts. In that context, teaching graphical modelling approaches, such as data modelling, is also relevant because they provide insights into the manner of thinking and designing artifacts of computer science-related disciplines. In theses disciplines, graphical modelling is an essential core component of the curriculum, e. g., [As18]. Commonly used languages are Petri nets, Event-driven process chains (EPC), Business Process Model and Notation (BPMN), Entity-Relationship diagrams (ERD), or Unified Modeling Language (UML).

Due to the complexity of the topic, courses with a high number of participants cannot provide individual support in solving modelling tasks, as there are often multiple correct

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solutions. This makes individual coaching with individual feedback on the modelling solution especially important. Digital exercises and exams as well as automated feedback generation for models have been developed and used at various universities over the past decade (e.g., [SG14; Th16]). However, up to now, most of them have been isolated solutions tailored to the individual situation of each university and course. Moreover, many solutions focus on plain model creation tasks, while learning objectives at higher levels, which emphasize competence orientation, are rarely considered appropriately.

We see this as a major obstacle in improving the quality of teaching and learning. Hence, we started a collaborative research project to set up a methodically grounded, integrated e-assessment platform that can be applied to multiple assessment scenarios. This includes the support of different graphical modelling languages, task types, and levels of modelling expertise. The platform will merge existing technical applications into a uniform concept that can be adapted for different courses in specific contexts. The platform shall be designed to enable (i) the extension towards additional modelling languages and (ii) an individual adaptation to the requirements of the respective institution and course by means of open interfaces, parameterisation and modularisation. The purpose of the paper at hand is to shed light onto the current state of research in the field of e-assessment for graphical modelling and to outline the agenda underlying the ongoing research project KEA-Mod.[6]

2 Conceptual Foundations

Designing and understanding models are core competences of graphical modelling. According to learning objectives for modelling in university education, students should learn “both to read and understand existing models and to build models” and "learn suitable modelling languages to the extent that they are able to apply the conceptual knowledge about modelling"[Gl08, p. 427]. In the taxonomy of Anderson and Krathwohl (revised according to Bloom) [An00], those objectives can be classified into the categories “applying” and “analysing” that form the intermediate level of competences. We also consider verifiable learning objectives for modelling at the two highest levels, “Evaluate” and “Create”, of the taxonomy as most relevant, since they appropriately reflect the actual practice of modelling.

Tasks on *model understanding* usually present complete models to students and ask different questions about them. Examples are questions about the correctness of a model regarding the syntax or about the meaning, i. e., whether a certain statement is actually covered by the model. For automated assessments, such task types can be implemented with multiple choice questions. The advantage is that student answers can be checked automatically and that an automatic generation of possible answers is feasible. This allows for the automation of the exercise creation, so that individualized, adaptive examination formats can be enabled.

[6] Kompetenzorientiertes E-Assessment für die grafische Modellierung (KEA-Mod), gefördert vom BMBF (FKZ: 16DHB3022-16DHB3026), `https://keamod.gi.de/`

Tasks on *model creation* typically provide a textual description of a situation. Students have to translate that into a graphical model using a modelling language. In addition to mastering the modelling language, cognitive skills such as text comprehension and abstraction are essential for solving the task. Grading such tasks manually is at least time-consuming if not also error-prone due to inconsistencies or accidental mistakes. A (partially) automated check can reduce the error rate, ensure transparent and consistent feedback, and save a lot of time. However, these benefits are based on formal digital models and cannot be achieved with hand-drawn diagrams. In current teaching and assessment methods, solutions are still mostly drawn on paper. Hence, they are often less readable and the manual correction effort for the grader is additionally increased.

A wide range of tools is already available for the digital creation of models. Most of those tools include support functionalities that check essential syntactic rules of the modelling languages, making it difficult or even impossible to violate these rules. Since teachers might be interested in assessing their students' knowledge of those syntactical modeling rules, they cannot use any existing tools for this learning objective (this would be analogous to testing the students' knowledge of spelling rules using a tool with automatic spell checking). Hence, any input editors used for teaching purposes must be limited in this respect.

The *competence-orientation* of the curricula reflects a central content-related and didactic claim of the reformed bachelor's and master's programmes. The course design should not only be based on a clearly defined competence profile and corresponding goals, which particularly represent the professional requirements of graduates, but should also include teaching and learning methods designed towards the acquisition of competence and corresponding examination tasks and formats. However, this requirement is often met only rudimentarily in the conception and implementation of the curriculum. So far, few studies have been conducted that explicitly deal with a subject-related didactic competence model for modelling in higher education teaching. In a superordinate competence framework model, the competence to model information systems is of central importance, although requirements for the use of modelling languages and tools have not been specified in detail so far in this model [Li13]. Regarding this goal, a discussion of curriculum development and learning objectives for modeling in university teaching [Gl08] has been published.

3 Existing technical solutions

In general, e-assessment systems for complex examination formats are already used in many places in the higher education sector, e. g., for checking source code in programming tasks [KJH18]. Although different approaches for computer-aided analysis of student solutions for graphical modelling are described in literature, their use in higher education is not yet widespread. While implementations of e-assessments for graphical modelling have been known for almost 20 years [Ts02], they are primarily concerned with the basic feasibility of e-assessments for this type of artefact and neither with the subject-specific challenges of certain model types nor with the direct connection to a competence-oriented teaching and examination concept. These early approaches demonstrate the inherent structural commonality of the different model and diagram types used for graphical modelling (e. g., ER, UML, BPMN, EPC, Petri nets): each of them is a specific graph in which different node elements are connected to each other via edges. These common properties can be used to develop a cross-language technical solution. Previous work demonstrated that the transferability of existing approaches to other model types of the same nature (graph structure) can be implemented with little effort [Fe16].

Since the basic technical feasibility has been established, current research focuses on three remaining technical challenges. First, there is an inherent ambiguity of modelling problems that allow for more than one correct solution. In order to be able to accept different correct solutions, current systems do not only rely on the fixed comparison of a student solution with sample solutions, but use rule-based approaches [SG11]. Solution specifications are divided into smaller sections, whose correct implementation can be checked individually and provided with feedback. Second, also a linguistic ambiguity of model element labels can cause uncertainties in the semantic interpretation. Current approaches take synonyms, typing errors, abbreviations, and alike into account or apply distance measures, text transformations, and other methods of natural language processing to deal with such ambiguities. Finally, execution semantics have to be considered for model or diagram types for which a purely static examination of semantics is not appropriate. To test the execution semantics of models or diagrams, similar techniques as in the checking of programming tasks can be used. Depending on the model or diagram type, all conceivable or only selected sequences can be simulated and compared with a specification [SG14].

Among the different diagram types used in teaching, the automated assessment of ER and UML class diagrams in particular has attracted the attention of researchers (e. g. [WE15]). A web-based software prototype based on the tool *RefModMiner* enables the automated assessment of EPC diagrams [Th16]. The automated assessment of student business process models in the form of Petri nets can be coupled with user feedback and a gamification approach [Pf16].

4 Remaining challenges and questions to answer

In order to achieve progress beyond the current state, several questions must be answered before an improved e-assessment platform can be developed and applied in regular lectures. The *first question* addresses the relation between required modelling competences in professional tasks and the learning objectives in university curricula. Looking only at one of the two sides would risk missing relevant aspects. We assume that reviewing existing research on professional modelling activities and curricula can contribute to finding answers. We plan to use questionnaires to gather additional information if necessary.

The *second question* aims at finding out which competence-oriented formats and task types are actually used at which point in the teaching/learning cycle to promote certain competences. It has to be captured which subject-related cognitive performance and competences are addressed by identified task types. Here, several task types might be suitable to measure a specific competence. At the same time, the complexity of modelling tasks makes it very unlikely that one task type corresponds to exactly one single competence. Hence, inferences and dependencies must be carefully analysed. To this effect, examination and exercise material currently used in higher education has to be reviewed.

The *third question* aims at finding out which task types address higher cognitive levels (applying, analysing, evaluating, creating) in an appropriate way. Only a certain subset of all potential modeling task types will be integrated into the e-assessment platform. However, not every relevant task type might be technically suitable for automation, so a further challenge is to find out which competences can be promoted by task types that can be (i) individually and adaptively generated and (ii) completely automatically checked. Notably, it is not the goal of the research project to change exercises so that they fit the current capabilities of existing e-assessment tools. Instead, the goal is to extent e-assessment features to cover as much of all relevant exercise types as possible. Potentially, the answer to the third question reveals that existing competence-oriented assessments are not suitable or sufficient regarding their relevance to learning objectives and competences. Then an additional question has to be answered on how to change or modify assessment procedures/criteria in order to establish the desired correspondence between learning objectives and competences. With the developed list of competences and related task types, the final question is how to design automated individual and elaborated feedback for various learning scenarios.

System usability is a further important topic. Since students and lecturers are two equally important user groups with different requirements, a careful analysis based on media pedagogy and instructional design should be carried out. From a media didactic point of view, it can also be important to enable the platform functionality to be embedded in the existing technical infrastructure of the respective university. In order to achieve this, the platform will be implemented on the basis of a micro-service system architecture, enabling the integration of existing technical solutions. In addition, the basic requirements for a modular adaptation and maintenance are given, such that small and clearly arranged system components can be extended or exchanged without affecting the functionality of the overall system. Cloud-based implementation also allows access to the platform independent of location and time. The digital processing of student solutions on the platform also opens up the possibility of learning process analyses in the sense of *learning analytics*.

5 Conclusion

We have identified several open questions that need to be answered on the way towards an automated assessment of graphical modelling competences which can significantly contribute to the education of future BPM experts. While there is a lot of promising research on the technical aspects of model analysis, feedback generation and exercise generation, a strong connection to competence measurement is still missing. Against this background, we are currently working with teachers, practitioners and fellow researchers towards the creation and validation of a suiting competence model and related assessment tools which shall be integrated in an overarching platform for automated assessment of graphical models.

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