Preparing Educational Standards in the Field of Object-Oriented Modelling

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Abstract: In Germany the results of the international PISA study disclosed a demand for an increase in the quality and an improvement in the comparability of educational results. In the subjects German, maths and first language (i.e. English) this demand already resulted in the development and publication of first educational standards. With the aim to prepare educational standards for the Informatics field of object-oriented-modelling (OOM) at first characteristics of such standards were analysed. It was justified that learning subjects from the OOM field fulfil current learning objectives of Informatics education. To prepare a competence level model for OOM, an important component of educational standards, a method was presented for selecting, abstracting, analysing and structuring exercises, which has effectively been applied to more than 320 exercises and also successfully been tested in Informatics education. Especially by the structuring step of exercises according to their dimensions Informatics core, subject and exercise type, a good basis for the justification of a competence level model is given. The results of this analysis were finally combined with the PISA competence level for maths to an outline of a corresponding model for OOM.

1 Motivation

The results of the international PISA- and the additional PISA-E-study showed that in Germany and its federal states the performance of the learners in secondary schools varies more than in any other participating country. While in the upper performance ranges Germany can keep up with most of the OECD countries, in the lower ranges the German learners considerably fall behind the participants of other countries [Ba02]. This was interpreted as a hint of a lack of minimum standards, which must be achieved in the education of e.g. reading and mathematical competence. While the German educational system so far was only controlled by the input, e.g. curricula and examination guidelines, nowadays a shift towards output orientation, e.g. towards the performance of schools and above all towards the performance of learners, can be observed.

As a consequence the German Ministry of Education and Research commissioned German educational researchers to investigate the development, implementation and consequences of national educational standards to increase the quality of school education, the comparability of secondary school qualifications and the perviousness of the educational system. First results were published in 2003 [GMER03a] and influenced the work of the Standing Committee of the German Federal Ministers of Education and Cultural Affairs, which passed first educational standards for 10th grade in the subjects German, maths and first language in its resolution from December 4th, 2003 [CMEC03a, b]. In the future the fulfilment of such standards will regularly be checked. Since the further development of the German system for secondary education by the introduction of nationwide educational standards is a wide-ranging intervention in a well-established school system, all subjects and its didactics, teachers and teacher educators as well as the school administrations need to be involved in this process.

In the subject Informatics the development of nationwide educational standards is impeded by the fact that in contrast to almost all other subjects still no binding basic education exists for all learners. Existing educational recommendations, curricula, educational concepts and lesson examples moreover show that there still exists no generally accepted consensus about the competences learners should acquire and the exercise classes learners should be able to manage.

This paper concentrates upon the development of educational standards in one important field of Informatics education, namely object-oriented modelling (OOM). The important role of OOM within secondary Informatics education was shown in [Br04a]. It was shown and justified, how the components of a so called didactic system (for OOM in this case), a compound of traditional and new components of the learning process with so called exercise classes, exploration modules and knowledge structures as main constituents, can be applied to prepare educational standards in the OOM field.

2 Method of research

With the aim to prepare educational standards for the field of object-oriented modelling, general components and quality criteria of educational standards are analysed on the basis of publications. Essential components in this context are the educational objectives to be reached, a step-by-step model of the competences to be reached by the learners as well as exercises and testing methods to verify the reaching of certain competence levels. The connection with the aims of a general, secondary Informatics education is realized by the linking with publications from the field of didactics of Informatics and with general educational guidelines. For the preparation of a competence level model a method for the analysis of Informatics exercises and for the development of so-called exercise classes, which was developed and successfully tested by the author, is applied. As a part of this method exercises become classified due to the dimensions Informatics core, subject and exercise type. Identified values of these dimensions are used to identify different levels of demands. Afterwards the results from this analysis are combined with the PISA competence level for maths, which due to analogies seems very appropriate as a basis for the Informatics field of modelling.

3 Components and characteristics and of educational standards

Educational standards take up general educational objectives. They lay down, which competences children and young persons should (at least) have acquired until a certain grade. The competences are described so concretely that they can be illustrated and implemented in exercises and in principle be measured by the help of testing methods [GMER03a]. *Good* educational standards relate to a certain learning field and work out the discipline's basic principles, do not cover the whole width of the learning field but concentrate on a core field instead, focus on competences, which have cumulatively and altogether been built up until a certain point in the course of a learning history, express minimum requirements, which are expected by all learners, are formulated clearly, concisely and understandably and are challenging for learners and teachers but attainable with realistic effort [ibid.]. In contrast to other definitions competences are understood in this context as available or learnable cognitive abilities and skills to solve certain problems as well as the involved motivational and social readiness and ability to apply the problem solutions in variable situations successfully and responsibly.

To benefit of educational standards within the quality development of schools, educational objectives need to be considered and competence models and exercises as well as testing methods need to be developed. Educational standards orientate themselves by ***educational objectives***, which the learning in schools shall follow, and implement them into concrete demands. They put these objectives in concrete terms in the form of competence demands and lay down, which competences a learner should have available, if important school objectives can be considered to be reached. These demands are systematically ordered in ***competence models***, which present aspects, levels and courses of development of competences. The determination of competence levels to establish minimum educational standards is a main research goal. Educational standards as results of learning processes finally become illustrated in ***exercises and testing methods***, with which the competence levels learners have reached can reliably be captured with empirical research methods. Since this is a time consuming process, the first published standards referred to a middle level of demands [CMEC03a, b].

In the following the dimensions *educational objectives*, *competence model* and *exercises and testing methods* are analysed for the field of object-oriented modelling.

4 Development of educational standards for the OOM field

4.1 Educational objectives

At the sight of the rapid development of Informatics as a science, the objectives of Informatics education are a continual subject of the didactic discussion since the origin of the school subject. Important results for the aim of this paper were the "Fundamental ideas of Informatics" by Schwill [Sc97], with which selection criteria for concepts for school education were made available, the "Information centred approach" by Hubwieser [Hu97], in which the importance of modelling for Informatics education was justified in detail and the overall conception of secondary Informatics education [Br00] by the German Informatics society (GI), in which long-lived guidelines for Informatics education were described. These guidelines are "interaction with Informatics systems", "working principles of Informatics systems", "informatic modelling" and "interaction between Informatics systems, human beings and society". Finally, in the revised version (Feb. 2004) of the uniform examination requirements of secondary Informatics education [CMEC04] modelling is also one main area.

In [Br04a] it was shown that learning subjects from the OOM field fulfil the selection criteria of Schwill. OOM is one essential style of modelling in Informatics, of which the educational value was widely stressed.

4.2 Identification, structuring and testing of exercise classes

The starting point for the identification, structuring and testing of so called *exercise classes* was the identification of a lack of lesson suitable exercises for applying, practising and deepening of contents of object-oriented modelling. In contrast to this in professional textbooks a big variety of such material exists. So, the existing material was analysed, and a method for developing corresponding material for secondary Informatics education was justified, applied and evaluated [Br04a, b]. This method not necessarily needs to be applied to professional material. In principle it can easily be adapted to fields of secondary Informatics education, for which already material exists. For the development of a competence model especially the analysis of Informatics cores, subjects and types of exercises combined with the development of exercise classes is of relevance. In the following, essential steps of this method are summarized (also see figure 1).

1. **Selection of textbooks**

   The starting point was given by the selection of standard text books on OOM with the prerequisite to contain exercises. The textbooks of Rumbaugh et al. [Ru91] and Balzert [Ba99] were selected.

2. **Selection of exercises**

   Since the contained exercises addressed different target groups, namely Informatics students or computer scientists, criteria to select or to transform unsuited into suitable exercises for secondary education were developed. In the first run of the method the criteria *concepts of secondary Informatics education*, *emphasis of modelling*, *language independency* and *complexity* were justified and applied. It turned out that the complexity of exercises should not already influence their selection for a collection, because this restriction is unnecessary. Not before the design of exercises for concrete learning groups and their learning histories, assumptions about suitable levels of demands can be taken. Therefore, the criterion of complexity was no longer applied in the second run. Altogether more than 320 exercises were analysed.

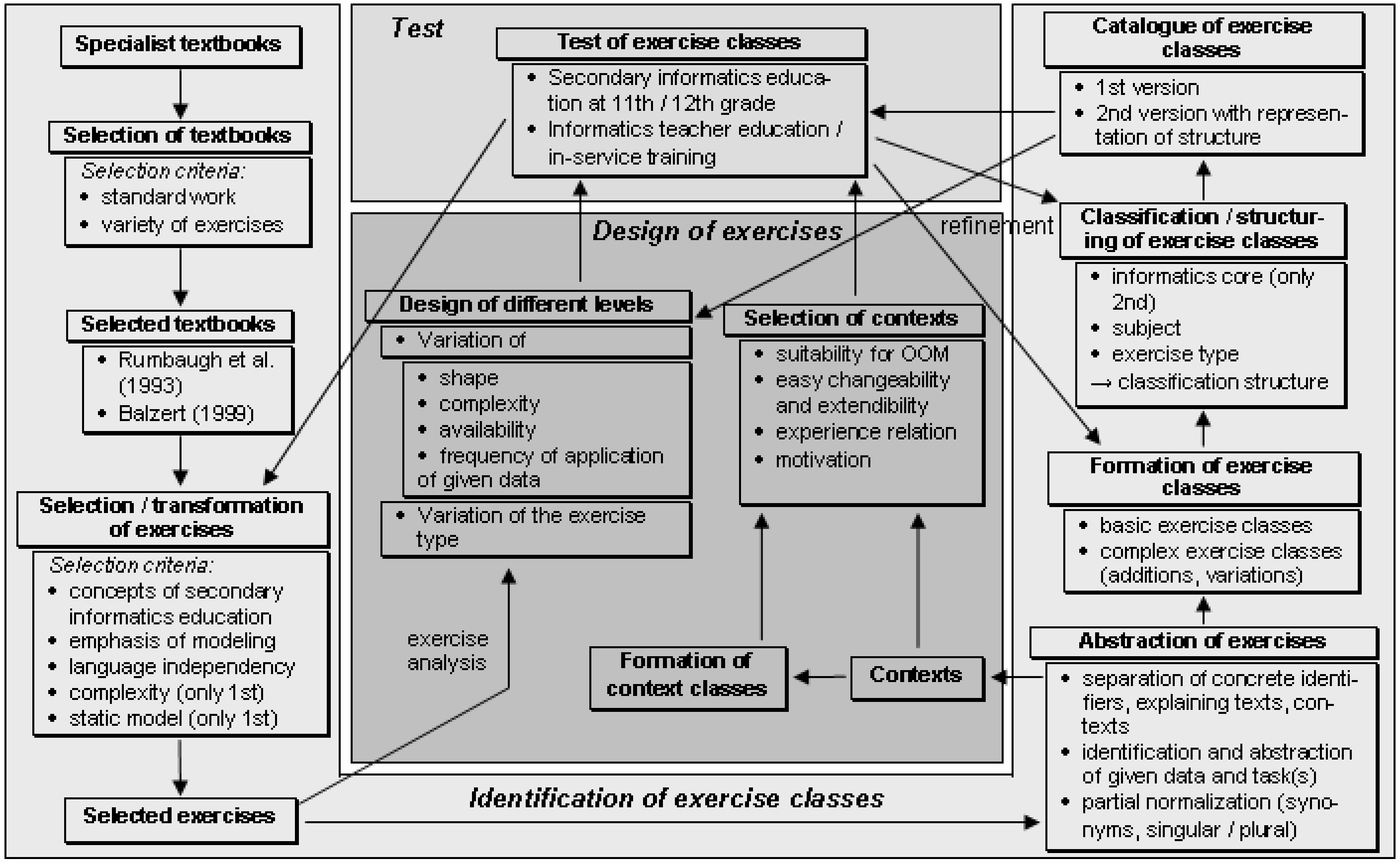

Figure 1: Development of exercise classes

3. **Abstraction of exercises and development of exercise classes**

After the selection the exercises were abstracted into so called exercise classes by separating them of explaining texts, real world contexts and identifiers. Every exercise class combines some given information (texts; figures, e.g. diagrams) with a task (basic exercise class). If for a task following additional tasks or alternative tasks exist, the exercise class is a complex one. It was necessary to identify different concept definitions (e.g. object diagram) within the analysed textbooks and to consider these definitions in the formation of exercise classes.

4. **Structuring exercise classes**

The next goal was to structure the exercise classes in a collection to simplify the access for teachers and learners. Therefore, the identified exercise classes were classified in view of their characterising dimensions *Informatics core*, *subject* and *exercise type*. In the field of the Informatics core exercises on the *static model*, the *dynamic model* and the *combination of both* were identified. The subjects of exercises were differentiated into *exercises on concepts of object-orientation*, *exercises on model elements* and *exercises on model.* Moreover, the exercise types *knowledge question, comprehension question, description task, assignment task, specification task, arrangement task, discussion task, analysis task, comparison task, validation task, identification task, modification task, transformation task* and *construction task* were identified. These exercise types were combined with the levels of the Bloom taxonomy of cognitive learning objectives and it was explained that exercises can be designed for all cognitive levels of demands. A collection of exercise classes was developed in two versions. At first, a preliminary study took place on the basis of exercises only on the static model to investigate the soundness of the concept. These exercise classes formed the basis of the tests in secondary Informatics education as well as in Informatics teacher education. The evaluation showed the soundness of the concept and the demand for exercise classes also on the dynamic model as well as on the combination of static and dynamic model and therewith initiated a second run.

5. **Design of exercises with exercise classes**

The findings of the tests in Informatics teacher education led to the development of a method for the design of exercises with exercise classes. Therefore, the selected exercises were structurally analysed with regard to the criteria *shape*, *complexity*, *availability* and *frequency of application of given data* and it was justified, to what extend, by their variation in combination with a suitable choice of exercise types, levels of demands in exercises can be modelled. Since besides exercise classes motivating contexts are necessary for the development of exercises, within the process of abstraction of exercises the separated contexts were analysed and the criteria *suitability for OOM*, *easy changeability and extendibility*, *every day life reference* and *motivation* for their suitability for lesson usage were derived.

6. **Testing of exercise classes**

The first version of the exercise classes was the basis for three empirical case studies in secondary Informatics education in grades 11 and 12 of two grammar schools in the Dortmund area in Germany. On the basis of these exercise classes, worksheets with OOM exercises were developed in cooperation with the teachers of the Informatics classes and a written questioning of the learners to grasp the educational success in the non-cognitive field was planned. All classes were sit in in spring 2002 at the processing of the exercises at two resp. three dates each. The anonymised solutions of the learners were collected and analysed afterwards. The learners were given prepared solutions instead. In the end of the case studies, the learners were asked to fill in prepared questionnaires. Altogether the soundness of the conception was shown. As important findings with regard to the further development of the conception a refinement of the inner structure of the exercise classes to simplify the selection for teachers, an extension to the field of dynamic modelling and its combination with the static model and a provision of additional and alternative tasks to better prestructure the way of solution of complex exercises were identified. Within Informatics teacher education it turned out that the student teachers had difficulties in creating exercises for different levels of demands because of a lack of experience. Therefore, the development of a method for creating exercises for different levels of demands was initiated. In in-service teacher trainings the broad acceptance of the teachers turned out, but also the demand for concept-oriented in-service teacher trainings in this field, since for many teachers OOM is also a new teaching subject.

4.3 Evaluation of Informatics cores, subjects and exercise types in view of a competence level model

By the analysis of ***Informatics cores***, ***subjects*** and ***types of exercises*** on object-oriented modelling (see point 4) basics for setting up levels of demands in a competence level model are given.

With regard to the ***Informatics cores*** it can be realized that in the modelling process the static model usually is constructed before the dynamic one. Afterwards the static and the dynamic model are developed further in an interlocked way. Published lesson experiences and results of lesson visits showed that this is also a suitable way for structuring the learning process. Nevertheless examples can be found, in which the dynamic model (e.g. use case model) served as the starting point. For the development of a competence level model no cause is given to prefer one of the two ways. It is obvious though that the combination with the respective other model represents a higher level of demands, because therewith tests of the consistency of the overall model are combined.

The ***subjects*** of exercises on OOM were classified into concepts of object-orientation, model elements and models. Concepts of object-orientation can be divided into basic concepts (e.g. object, class) and advanced concepts (e.g. design patterns). The broad tendency of the exercises on basic concepts is on a lower level of demands than the exercises on advanced concepts. A similar relation goes for exercises on model elements resp. on models. The specification of an attribute (model element) is simpler than the specification of all attributes, methods and relations within a class model (model). Accordingly it can be justified that exercises on basic concepts resp. on model elements can be assigned to a lower level of demands than exercises on advanced concepts resp. on models.

It was shown for the identified ***exercise types*** on object-oriented modelling that they cover all levels of cognitive learning objectives according to the Bloom taxonomy [Br04a, b]. The broad tendency of the exercise classes, which belong to the lower levels according to Bloom, can be found with lower levels of demands. The same applies to the higher levels. Knowledge and comprehension questions can be assigned to all levels of demands as well as description tasks. Assignment tasks are especially suitable for the lower levels, because they take away the difficult process of identification from the learners. Specification tasks are again suitable for all levels. While on the lower levels the learners specify e.g. simple attributes, they specify on the higher levels complete models. Discussion, analysis, comparison and validation tasks are possible from a middle level of demands on and can be extended on higher levels accordingly. Identification, modification, transformation and construction tasks are possible on the lower and middle levels only, if they are formulated concretely enough and are accompanied by very illustrative material. On the higher levels, increasingly more open exercises are possible.

5 Outline of a competence level model for OOM

An important finding of the PISA study was that competence levels of a subject can be structured according to the content as well as according to important subject specific activities. In the field of Informatics it was proposed by Friedrich to structure the competences in the content dimension according to the guidelines of the overall plan for secondary Informatics education of the German Informatics society (see above) and in the process dimension according to the PISA competence levels [Fr03]. Puhlmann structured the learning of Informatics content in the form of the competence classes "application", "development" and "decision" [Pu03]. It is an open question, if the proposed levels are suitable to structure all or only some fields of Informatics education. The following outline of a competence level model for the field of object-oriented modelling is also based upon the PISA model for maths [GMER03a], which is on account of analogies especially suitable as a basis for the informatic field of modelling, also because the PISA model is based upon the criteria for good educational standards (see section 3). For example it is quite clear that the first two criteria are fulfilled, because the OOM field belongs to the basic principles of Informatics and is among others one core field of the discipline. Publications from the didactics of Informatics were included to graduate concrete learning subjects on the basis of experiences.

Level 0: Cognitive and planning preparation of object-oriented modelling

Learners, who belong to this level, are able to make out and to classify *concrete* objects. They are able to take apart objects into pieces in a structured way and to cognitively grasp and analyse either hierarchical or tree-like structures. They have available basic planning abilities, which enable them to construct, to cognitively grasp and to manage hierarchical modularisations of plans.

All mentioned aspects are essential prerequisites for analysing and designing structures of object-oriented models. Schwill showed 2001 [Sc01] that this level usually becomes reached at the age of primary education. Level *0* was intentionally labelled so to indicate that in contrast to all following levels this preparation does not require any kind of primary Informatics education.

Level 1: Elementary object-oriented modelling

On this level, simple object-oriented modelling (e.g. of text documents in a word processing software) is carried out by the use of simplified object and class diagrams (static model). Learners, who belong to this competence level, are able to identify objects, to assign attributes and methods to them and to abstract objects of the same kind into classes. A very clear modelling subject is required as well as support of the learning process by suitable figures, tables or learning media (e.g. exploration modules [Br04a]).

The modellings carried out serve for building up the technical Informatics language on object-orientation on the one hand and as mental models of the modelling subjects on the other. Voß showed 2003 [Vo03] that learners in lower secondary education manage the learning process of the application of word processing software better, if they analyse and develop object-oriented models (reduced class diagrams) of text documents dealt with, instead of only relying on the online help documents included in the software.

Level 2: Object-oriented modelling and conceptual linking

Learners on this competence level are able to combine different concepts of object-oriented modelling to solve problems, if texts or figures guide the solution process. They are able to describe and to analyse simple given object-oriented models as well as to modify and to extend given partial models within limited scope. The learners on this level are also able to assign terms given in term lists to the categories object, class, attribute, method or relation. The independent identification of concepts in texts or figures is possible, if these materials support corresponding assignations.

In [Br04a] it was shown that learners in upper, without an educational background in Informatics from lower secondary education are able to manage such exercises. However, according to the level of demands, it seems appropriate to assign such exercise types to lower secondary education. It is a problem that in Germany still no binding Informatics foundation for all learners in lower secondary education exists.

Level 3: More extensive object-oriented modelling on the basis of demanding concepts

Learners on this competence level are able to build up object-oriented problem solutions (e.g. a static and dynamic model) over several interim steps. More open modelling exercises are managed in which among various designing possibilities suitable ones need to be chosen.

In [Br04a] it was shown that reaching this level requires competence in the steps of the object-oriented problem solving process. Learners in upper secondary education, for who the process was structured by given tables or figures (e.g. partial models), managed it without significant problems. Learners, for who the process was only structured by the declaration of steps, showed difficulties, if the steps were not practised enough before.

Level 4: Advanced object-oriented modelling and assessment of models

Learners, who can be assigned to this competence level, are able to cope with very open formulated modelling exercises, in which object-oriented models must be developed after a very thorough analysis of exercise texts. They have good command of the necessary core of an object-oriented modelling language (such as UML), of essential steps of an object-oriented process model as well as of advanced object-oriented concepts (e.g. design patterns) and are able to systematically apply the steps without further structuring help. Essential components of the problem solution process are informatic explanations as well as reflections about the modelling process itself.

Schulte showed 2004 [Sc04] that learners in upper secondary education are able to systematically apply steps of an object-oriented modelling process to solve given problems and that this way they develop more sophisticated mental models of software development than it is achieved in traditional Informatics education.

6 Conclusion and further work

In this paper a method for systematic analysis of exercises was presented and it was shown, to what extend the results of the analysis of exercises on object-oriented modelling can be used to prepare a competence level model, which is needed for the development of educational standards. An outline for a competence level model based upon the PISA maths model was presented. To validate it, systematic tests combined with empirical research are necessary. Moreover, the different approaches for learning and teaching object-oriented modelling at the levels of lower and upper secondary education as well as of early higher education need to be combined to a continuous spiral curriculum for secondary Informatics education under consideration of the special school organisational conditions for the subject Informatics, to refine the model proposed here therewith.

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