

Modeling: A CS Concept for General Education

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Abstract— For all computer scientists the term ‘modeling’ is well known. It displays an often-used method, which is applied in each field of computer science to investigate, describe and plan problems or structures. With the help of models, large and complex structures are divided into smaller parts, which leads to a better understanding of the problem and often provides input for the solution. With the help of different types of models, different perspectives of one problem can be observed and discussed. These processes are not only part of computer science respectively computational thinking. Problem solving skills are needed in any domain and should be trained as well as possible in primary and secondary education. This could be supported by the computer science concept of modeling including processes like reduction, decomposition, abstraction, generalization etc. and appropriate techniques like UML Unified Modeling Language or the Entity-relationship model. We suppose that a consequent use of modeling beginning in different subjects during primary and secondary education can train and improve problem-solving skills. Before being able to verify this hypothesis, it is necessary to find a way to integrate modeling in schools despite of not being part of the curriculum. This is one aim of our project “Informatics – A Child’s Play”, which tries to implement different computer science concepts in different subjects of primary and secondary education. To reach this goal we firstly have to convince and train teachers. In this paper some topics of modeling are presented as they were adapted for workshops in primary and early secondary education considering the age and interests of the students as well as topics taken from their surroundings. Furthermore, we present first evaluation results concerning its acceptance and usefulness for teachers and students as well as their performance in understanding and applying modeling in different lessons.

Keywords—models, diagrams, general education, Entity-Relationship-model

I. INTRODUCTION

In today’s society, technology affects nearly everybody in different occupational fields and has therefore a deep impact in everyday life. It is obvious that more and more experts in technical areas are needed to develop, produce and service new artefacts. To reach children as early as possible the project ‘Informatics – A Child’s Play’ came to life. The main aims of it can be summarized as follows:

- Arousing interest in informatics¹, engineering and technology as early as possible.

- Improving and consolidating students’ and teachers’ knowledge about informatics (concepts, usage, career, etc.).
- Fostering general learning skills like text comprehension, problem solving, logical thinking or creativity.
- Developing and evaluating brain-friendly teaching material.
- Establishing computer science concepts in the long-term in primary education (a lot of them are already part of the Austrian curriculum for primary education, but are not recognized as such).

During the preparation phase of the project different existing workshops, which partly based on ‘Informatik erLeben’ (Experiencing Informatics) [1] or ‘Computer Science Unplugged’ [2], have been adapted or new ideas were elaborated. Additional new material had to be developed because of the idea to integrate computer science concepts in different subjects and sciences. One link to establish such a connection can be ‘computational thinking’. In [3] computational thinking is called “[...] a fundamental skill for everyone” and it is proposed to “[...] add computational thinking to every child’s analytical ability” [3]. Further [4] describes it as “[...] a problem-solving methodology that can interweave computer science with all disciplines” and points out that it focuses on “abstraction, automation and analysis” [4]. Especially abstraction and analysis of problems and their solutions can be related to different types of diagrams and models. In the following chapter modeling will be defined and a connection between modeling and general education will be shown. Chapter 3 will explain the study with the research questions, methods and some ample units. In chapter four some first results of the study will be presented.

II. MODELING IN GENERAL EDUCATION

A. What is modeling?

In computer science, models are a very important and common form of representation in different areas or levels of development, e.g. the description of processes or problems, a program or an equation [5]. A model can be defined as “an abstract description of a real or planned system, including the

¹ The terms informatics and computer science are used as synonyms in this paper.

essential attributes of this system needed for a certain objective. Modeling can be seen as the creation of such description.” [5, p. 4]. That means that the term ‘model’ refers to a simplified representation of the real world and builds the base for the present work.

The process of modeling includes different working steps and thinking processes like reduction, simplification, abstraction, generalization, hierarchization, or classification. They can be summarized in the following four steps:

- Defining the scope: in this step the borders should be found, which define the part of the system that should be described.
- Abstracting: During this step, unimportant details or special cases should be removed.
- Idealizing: the aim of this step is to ease the description by correcting non-ideal attributes.
- Describing: in this step the representation of the main attributes, like components, relations between components, interaction with surroundings, static structure or behavior of the system, are created with the help of modeling techniques [5].

The order of these steps can vary, depending on the modeling task.

B. Modeling in general education

Models are simplified representations of the real world. They can be represented in different ways (fig. 1): mental, physical or symbolic. Mental models – the first step in reducing the complex reality – describe the way people understand some domain of knowledge [6]. This happens in any domain and any subject in school. Hence, the concept of modeling is, in our opinion, definitely important for general education. The external representation of these mental models can be physical, like a scale model of a house, or symbolic in form of graphics, diagrams, or texts (verbal models).

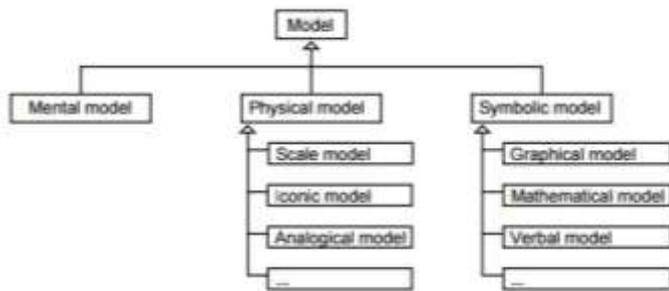


Fig. 1. Classification of models with respect to their representational form. [7]

Based on this classification, models and the process of modeling are part of any subject matter, in the curricula as well as in daily school life. Some subjects explicitly name the contents *models* or *working with models* in their curricula, e.g. mathematics, geometry, chemistry, geography or technical work. Other subjects use models or modeling without knowing it consciously. Verbal models, that “describe a system by means of textual information” [6] are part of every subject e.g. in form

of chapters in textbooks or summaries of texts in foreign languages etc.

Having a closer look to the process of modeling, its dimensions and the competencies needed like abstraction, reduction, simplification, classification, generalization etc. it becomes obvious that modeling is already an important, but mostly hidden part of general education. The primary school curriculum, for example, requires that

- teachers shall lead children to abstraction [8, p. 27]
- train the capacity of abstraction e.g. by using diagrams or symbols [8, p. 61],
- foster rational thinking processes by training basic cognitive processes like comparing, sorting, classification, abstraction, generalization etc. [8, p. 147].

C. Teaching Modeling: Techniques and Possibilities

For software development different models have to be used because each of them describes one aspect of the real system. To display the following aspects different modeling techniques can be used:

1. Structure: domain, entity-relationship, grammars
2. Attributes: domain, entity-relationship, logic
3. Relations: entity-relationship, logic
4. Behavior: finite automata, petri-nets, algebras, graphs [9]

As it can be seen the Entity-Relationship-model (ER-model) can be used to display three of these aspects. Therefore and because of its simplicity, this diagram type was perfect for our project.

This method of modeling was introduced by Peter Chen in 1976 [10] and is very useful to show objects with attributes and their relations to each other. In Chen’s modified notation it is easy to learn because its graphic notation includes only three basic shapes.

- An ‘entity’ is a collection of objects of the same type and is graphically displayed as a rectangle.
- A rhombus represents the ‘relation’ between entities.
- The ‘attributes’ of entities further describe these entities and are displayed as ellipses [9].

Lines between the shapes show their connection to each other.

III. THE STUDY

A. Research Questions and Methods

The study on the use of modeling concepts and techniques in general education is part of the research project ‘Informatics – A Child’s Play?!’ that mainly aims at introducing informatics concepts in different subjects of primary and lower secondary schools. Our main research questions concerning modeling are:

1. How and where can we introduce modeling in primary and lower secondary education?

2. Which modeling techniques are useful and practicable for teachers and students without informatics background?
3. Which dimensions of the modeling process are or shall be part of general education?
4. Is it possible to improve general learning competencies like abstraction, problem solving, text comprehension etc. by a frequent and varied use of modeling in primary and lower secondary education?

In order to answer these questions and to achieve a sustainable integration of the informatics topics, in this case “modeling”, different activities and research methods are necessary:

- *Development and implementation of teaching units and materials*
We developed new teaching units and materials based on existing curricula, topics, worksheets, activities etc. We gained data and ideas from content analyses of different curricula, interviews with teachers of different subjects as well as different worksheets and tasks that they provided us for the elaboration from the perspective of computer science. We offer different workshops for teachers and students in order to test and adapt the developed units and materials by considering findings of participatory observation, immediate feedback of the participants as well as interviews with teachers and students.
- *Usefulness and practicability of modeling techniques*
As the concept of modeling is not part of the curricula, we are firstly interested in the usefulness and practicability of modeling techniques for teachers and students without computer science background. To evaluate these aspects we use different methods, mainly immediate feedback, interviews with teachers and online-questionnaires.
- *Comprehension of modeling*
In order to assess the comprehension of modeling we analyze the answers of the participants to our questions during the workshops and we ask them to explain the concept of modeling to their colleagues. Furthermore, we evaluate their products – diagrams, posters and other materials. At the end of the school year, the students will also take a written test.
- *Assessment of general learning skills*
An eventual improvement of general learning skills like text comprehension or generalization will be evaluated by pre-post-tests. In part, we use standardized test, like some subtests of the HAWIK IV battery (matrices and finding generic terms) and the Salzburger Lese-Screening for the assessment of the reading comprehension.

B. Implementation of Modeling: Sample Units

We implemented the concept of modeling in two ways depending on the available time and/or the aim of the unit:

1. From a model to a text

2. From a text to a model

Both ways are useful and practicable (at least at a low level from the computer science perspective), but have different aims, advantages and disadvantages.

Starting from a model, e.g. the ER-diagram in figure 2 and 3, we can engage children to be creative. They can continue the diagram, tell or write a story, create similar diagrams for other topics of their choice etc. Furthermore, they can be used as example of how to represent subject specific knowledge in a structured way. In a first step, we introduce only the entities accompanied by the typical beginning of a fairy tale: “Once upon a time there was a knight and a princess. Suddenly a dragon appeared and ...”

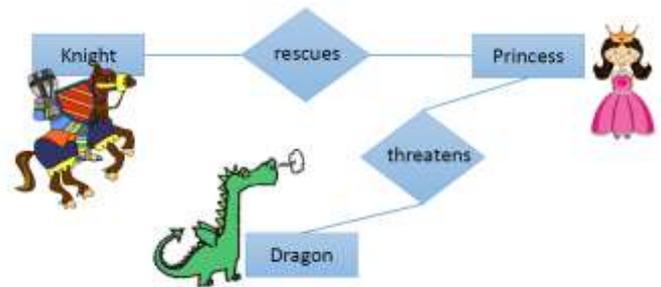


Fig. 2. 1st part of ER-diagram: Knight – Princess – Dragon

Then we show the relations (verbs) between the entities (nouns) and invite the children to continue the story together: “... and threatened the princess. But, the knight could rescue the princess.”

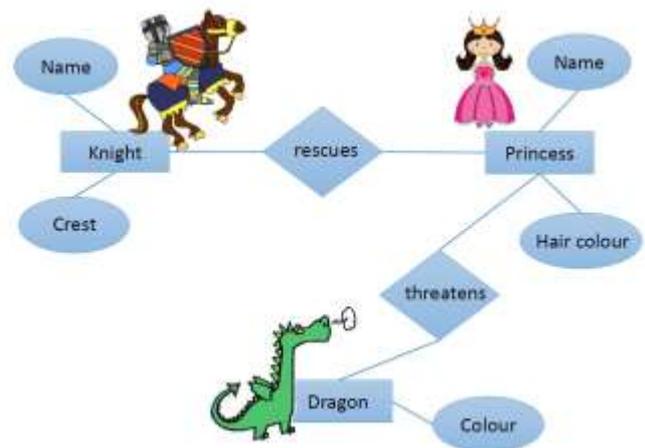


Fig. 3. Extended ER-diagram: Knight – Princess – Dragon

In the last step, we introduce the attributes or characteristics of the different entities. Besides telling the story, we introduce also the basic use of the different shapes: rectangles for entities (nouns like persons, animals etc.), rhombs for relations respectively verbs and ellipses for attributes (characteristics).

Depending on the available time, the children can now continue the fairy tale and/or extend the ER-diagram or even invent a new story. When the children continue the story, it is reasonable that the teacher should extend the diagram with

appropriate shapes (on the blackboard or by means of cards) containing correct entities, relations and attributes.

The second way of introducing models is starting from a sample text on knights, princesses and dragons, containing already the correct shapes for entities, relations and attributes (fig. 4). This task may help to train reading competencies and to extract essential information. Furthermore, comparing it with the pictures, it can be used demonstrate the difference between concrete attributes like 'green' and generic terms, in this case 'color'.



Fig. 4. Basic text for the ER-diagram 'Knight - Princess - Dragon'

IV. PRELIMINARY RESULTS

A. Practicability for teachers and students

Based on the interviews and discussions with 25 teachers in three workshops as well as the observation of students in primary and lower secondary schools we can definitely suggest modeling as a practical concept and tool for general education. All teachers said that entity-relationship diagrams are very useful for teaching and/or learning and that they would use them in one of their next lessons. However, as expected, most of them noted, that they would need more than one workshop before trying out the concepts on their own, because they were afraid of making errors. Only few teachers developed their own examples already after the first introduction into modeling, but rather as another form of mind map than as a correct diagram.

B. Comprehension of modeling

The answers and statements of the students during our workshops as well as the evaluation of their posters and diagrams showed that modeling seems easy to understand but sometimes difficult to apply. We evaluated the posters and diagrams of students from two points of view: On the one hand, we checked the subject-specific or thematic knowledge (not informatics) as well as their capability to extract the essential information of given texts. On the other hand, we corrected the diagrams from the view of computer science in two steps. Firstly, we evaluated the correct use of the notation, i.e. the correct shapes for the different functions respectively word classes. In the second step, we focused on computer science and the correct concept of modeling including generalization. The

division in two steps was necessary because of two reasons: On the one hand, when using e.g. ER-diagrams to visualize subject-specific knowledge or essential information of a text, it is often necessary to note some concrete attributes e.g. 'green' as color of the dragon in figure 3. However, using it in the ER-diagram it is not correct from the point of view of computer science, where models must contain generic terms, in the case above 'color' instead of 'green'. On the other hand, the process of generalization seems to be difficult for many participants. Hence, we decided to introduce generic terms only in a second step.

The first step was quite easy as mentioned by many participants. However, there are some striking aspects and errors from the view of computer science. Teachers and students tend to use ER-diagrams as another form of mind map. When designing an entity-relationship model most of the participants firstly concentrate only on entities (nouns) and relations (verbs), but seem to forget attributes. Furthermore, sometimes we found a verb and a noun together in one single shape, mainly when the noun is not the subject of a sentence as in the following example:



Fig. 5. Left: incorrect ER-diagram. Right: corrected ER-diagram

The second step respectively finding generic terms for the concrete names of adjectives of a text seems to be quite difficult for students as the immediate questions after the workshops, the observation of the students during the design of their own models as well as the assessment of the final posters showed.

V. CONCLUSION

Models are a basic concept for software developers and computer scientists. They are used to describe problems and can help to solve them. Competencies needed for the modeling process like abstraction, reduction, simplification, classification, generalization etc. shall be, in our opinion, part of general education. Some main aspects of modeling are even mentioned in different curricula of different subjects. Thus understanding these methods is useful for children of all ages. This paper should show different possibilities to integrate methods of modeling in primary and early secondary school. It focused on the entity-relationship-model and presented two ways to use this technique in a school unit. Following the opinions of participating teachers modeling methods are practical tools for teaching and learning. Students liked working with these concepts although they had some problems.

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