# Teaching Aids and Work With Models in e-Learning Environments

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**Abstract:** PISA study has defined several key areas to be paid attention to by teachers. One of these areas is work with models. The term model can be understood very broadly, it can refer to a drawing of a chemical reaction, a plastic model, a permanent mount (taxidermy) to advanced 3D projections. Teachers are no longer confined to teaching materials and aids available physically at schools. Thanks to information technology, models can be included in lessons almost without any limits. However, work with models is very specific due to the simple fact that a model always differs from what it represents. Efficiency of education using ICT can be affected negatively in case that work with complex models requires high level of abstraction which pupils are not capable of (Harrison and Treagust, 2000). Jančaříková (2015) points out that – due to the demands on upper secondary pupils – children must be taught how to relate models to real objects from very early stages. Linking an object to its model – isomorphism is the basis for successful work with models. Work with models thus must be developed systematically and consistently and included into teaching of younger learners. The scope of work with models in natural sciences is gradually increasing. However, the fact that we are able to project models to pupils using information technology does not mean that pupils will be able to understand them. In this paper we want to point out that not enough attention is paid to work with models (not only in the Czech Republic) – methodology of work with models does not exist and is not taught to pre-service teachers. The paper classifies types of models we come across in lessons, describes basic differences between objects and reality they represent and proposes possible ways of systematic inclusion of models into teaching.

**Keywords:** models, projection, science education, 3D projections, interactive models, science education, biology

## 1. Introduction

It is becoming more and more common that natural scientists study phenomena which are not tangible and cannot be observed with our own eyes (e.g. DNA double helix, cell, atom). Natural scientists make hypotheses about functions and structures of particles, organelles or phenomena that take place on or in them. These hypotheses are verified using models and computer simulations.

The verified knowledge is then transformed into curricula of different natural sciences. Virtual environments allow teachers to present this new knowledge to pupils and students in a relatively simple way.

However, very specific demands are put on pupils if they are to understand a projection or a model transformed into 2D form on a monitor. The need of scientific abstraction grows, namely the ability to work with models, projections and especially computer simulations in virtual environments. These demands are even higher if the pupil works with computer models in absence of a teacher, e.g. in self-study using e-learning. The more complex a model is, the more abstract thinking is needed to understand it. PISA studies show that work with models is very difficult for pupils and due to their deficient ability to abstract some pupils fail to understand what real object a model represents. Then they fail to grasp the phenomena going on in these objects.

This topic has not yet been paid enough attention by expert community. That is why we decided to focus on it in our research.

## 2. History of work with teaching aids in natural sciences

### 2.1 Third revolution in education

Eric Ashby (1972) speaks of four revolutions in education. From the point of view of the use of teaching aids, it is the last two revolutions that matter; the third revolution in education – use of textbooks and course books but more significantly the fourth revolution associated with the use of educational technologies. The fourth revolution is still an undergoing process.



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The beginning of the third revolution is connected with the name of Czech, or more precisely Moravian teacher and theologian from the seventeenth century, Johann Amos Comenius. Comenius was one of the first thinkers to use the printing press for enrichment of the process of teaching. Comenius' textbook *Orbis sensualium pictus* became the model and the source of inspiration for many generations of teachers and educators. Comenius elaborated his approaches further in the famous treaties *Didactica Magna*. Use of illustrative aids was advocated by many other teachers and educators, e.g. Jean-Jacques Rousseau.

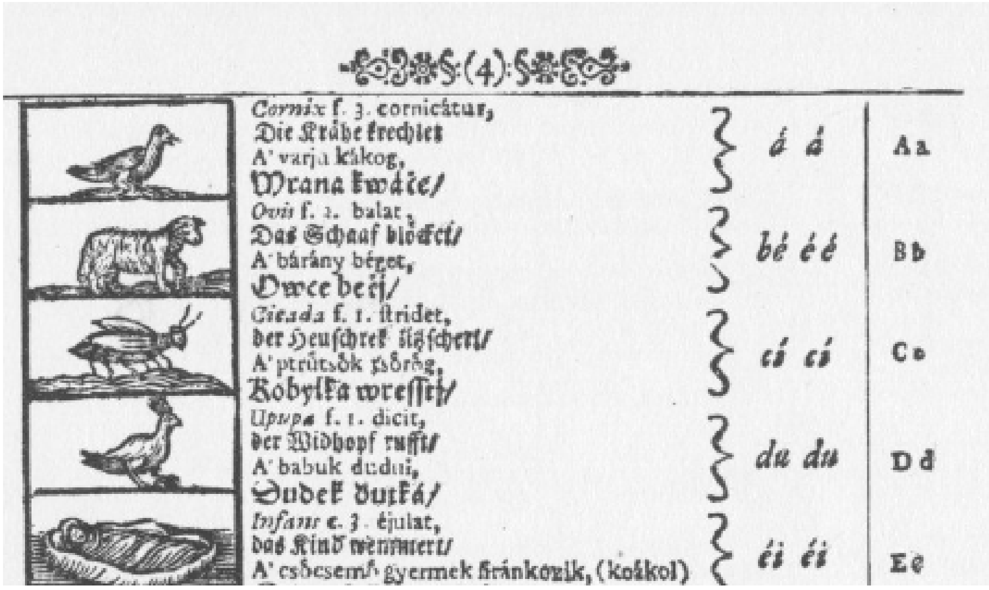


**Figure 1:** Comenius' Orbis Pictus

In fact, Comenius can be considered as the forerunner, if not the inventor, of modern programmed instruction (Seattler, 2004).

The famous Prussian educator and reformer Friedrich Eberhard von Rochow (1734 – 1805) followed Comenius in his pedagogy. It was thanks to von Rochow that elementary schools in Austria-Hungary added to trivium (reading, writing, elementary mathematics) natural sciences – knowledge of selected species of plants and animals, elementary knowledge of biology and geology and some knowledge of national geography and history. This was achieved by teachers through the method of *reading scientific articles with teacher's explanations,* i.e. a method proposed by Friedrich Eberhard von Rochow. The method was used for about 200 following years (Schmitt, 2001). The method was the first generally used method of teaching natural sciences on the territory of contemporary Czech Republic. In fact the method was the first attempt to transform the content didactically. His method is still used today.

## 2.2 Classroom equipment

Learning texts were not the only aids used when teaching natural sciences. In science education schools also used other aids such as maps, globes and collections of products of nature. The scope of teaching aids used at a particular school largely depended on the initiative of the teacher who was in charge of the collection. However, gradually classroom equipment was unified. For example The Educator's Encyclopaedia (Smith, Krouse and Atkinson, 1961) includes one complete chapter on Science laboratory equipment. It gives a list of several dozens of aids that form the basis of school equipment.

**Figure 2:** Historical furnishing and equipment of a school – open-air museum Polná, Czech Republic

Contemporary classrooms are very likely to be equipped with computer technology that allows teachers to use various multimedia and interactive materials. In some cases each pupil is working with a computer or other IT devices.

**Figure 3:** Vääksy Upper Comprehensive School, Finland – Art classroom and Gymnázium nad Alejí, Prague, Czech republic – Genetic laboratory

Some schools (see Fig. 3) do not only have the usual equipment but highly specialized classrooms and laboratories built thanks to sponsors or within the frame of research or development projects.

Apart from school teaching aids, teaching and learning can also be supported by using products of nature – living organisms and mounts. These are called model organisms.

A model organism is such organism that is explored by children/pupils not only to discover this one particular organism but also to develop the pupils' ability to explore and to raise their awareness of diversity of organisms.

A model organism is studied very thoroughly. Children and pupils are afterwards expected to be able to generalize and transform knowledge and methods to situations of exploring other organisms and objects.

Historically we come across several traditional model organisms, e.g. the earthworm or the bee, which are used already in textbooks for Austria-Hungarian schools.

**When selecting model organisms we should be guided by:**

- their availability – it is beneficial if they can also be observed and possibly even manipulated with spontaneously, e.g. in a school garden, or if they can be turned into semi-permanent or permanent mounts. That is why model organisms should not include rare or protected species.
- their representativeness – the organism must be suitable for studying the given topic (e.g. petals and pistil must be visible if exploring a blossom) and the findings from observations must be well generalizable (that is why any use of model species with unusual life cycles or species systematically marginal, e.g. a platypus, is not recommended when teaching science to very young learners; they get to know these later).
- the effort to cover as wide spectre of organisms as possible (model organisms should include representatives from all kingdoms, the plant kingdom should be represented by a herbaceous plant, bush, trees, both coniferous and deciduous etc., representatives of all phenomena (water and

terrestrial organisms, flying and non-flying organisms, organisms with complete and incomplete transformation, various types of fruits, organisms with various strategies of avoiding a predator, organisms with different form of maternal care etc.).

Model organisms can be studied in a school garden. This is a new trend that can be observed in many European countries – the use of school garden in science lessons. The trend is a reaction to criticism from 1960's when Edward Dale (1967) said that the typical approach to teaching biology in the secondary school today almost totally ignored the study of plants and animals in the field.

### 2.3 Fourth revolution in education – Use of technologies

The fourth revolution in education is still in progress and is characterized by major use of education technologies. Introduction of technologies into teaching changes teachers' and pupils' attitudes to teaching and learning. Modern technologies replace traditional methods of lecturing and the use of blackboards. Use of technology in classrooms falls into two categories. Use of technology by a teacher for explanation and teaching and use of technology by pupils for their own individual work. Both categories could be come across in lessons as early as the first half of the twentieth century. Availability of technologies has, however, changed a lot since those times. It has become more accessible but also the potential of its use has grown. In the 1930s' experiments with use of technology involved films and simple learning machines. Nowadays teachers and pupils work with computers with virtual reality. Still, similarly to the fact that textbooks are still used in lessons, classical aids still have their place at schools. Revolution in education has not resulted and should not result in replacement of the existing learning materials by something else. They should only be supplemented and enriched.

## 3. Learning theories, abstraction and models

### 3.1 Piaget and abstraction

Contemporary theories of learning very often come out of Piaget's claim (Piaget, 1979, p. 23) that knowledge does not result from a mere recording of observation without structuring activity on the part of the subject. Piaget explained that knowledge proceeds neither solely from the experience of objects nor from an innate programming performed in the subject but from successive constructions (Piaget, 1977, preface). This means that assimilation and reflective abstraction play a key role in the learning process.

Learning does not occur and cannot occur without a pupil's or a student's activity. When studying a new object or process, the pupil or student must be able to find the signs which link the studied object or process to already familiar objects and processes or must be able to see how they differ from these. With the help of generalization or abstraction the pupil or the student constructs qualitatively higher-level knowledge that incorporates the already acquired knowledge and allows its application on yet unfamiliar objects (Hejný, 2004). This process may repeat and pieces of knowledge are linked on various levels.

Models used in lessons support the process of cognition on several levels:

- they represent real objects, often those that cannot be reached easily, they allow learners to grasp these objects, their functions and processes that take place in or on them ,
- they allow learns to make links between the studied objects and already acquired knowledge (analysis and synthesis of knowledge), which is followed by construction of a new concept in their minds,
- they develop abstract thinking, pupils learn to create isomorphism (see Slavík, 2004).

### 3.2 How we learn

When using teaching aids, various senses are activated. This supports both learning and remembering. Sampath (1990) states that a pupil learns using different senses as follows:

- 1% through Taste
- 1.5% through Touch
- 3.5% through Smell
- 11% through Hearing
- 83% through Sight

This means that using visual perception in lessons is, without any doubt, essential if learning is to be effective. It is important to realize that when working with tactile, not only visual aids, we at the same time activate touch and smell, which makes for other 5 % of sources.

However, the process of learning is not decisive in what pupils actually remember. The way pupils work with information is of major impact on what they remember. Sampath (1990) uses the following classification:
Pupils remember:

- 20% of what they Hear
- 30% of what they See
- 50% of what they See and Hear
- 80% of what they Say
- 90% of what they Say and Do

Interactive materials that require from the pupil only passive watching will thus be much less efficient than materials which allow pupils to work in groups and which can be discussed.
Even more attention to further processing of information is paid by Dale (1969). He studied how much information we remember two weeks after we have processed it. The results of his research are presented in the following graph:

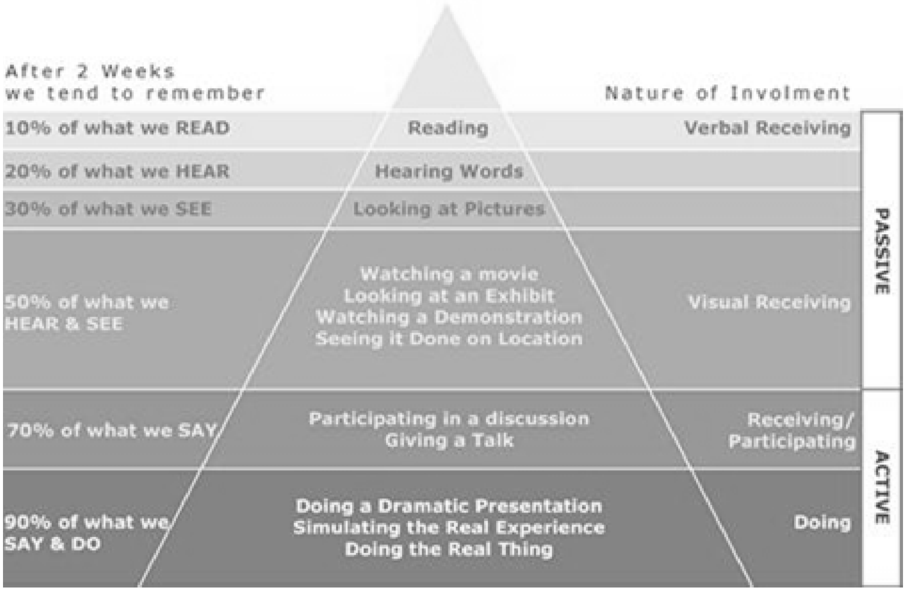


**Figure 4:** Cone of Learning (from litemind.com)

### 3.3 Generations Z and Alpha

Use of technologies may be regarded as a reaction to the changing needs of children and pupils. Since 19th century sociologists have been aware of the differences in acting of members of different age groups. Generations started to be categorized according to their unifying features and labelled by letters of Latin and later also Greek alphabet (confer Posnick-Goodwin, 2010). Of course the boundaries between different generations are not sharp. However, this approach allows us to classify, typologize and follow trends in society. One of these trends is alienation from nature. Contemporary schools educate generations Z and Alpha (on primary school level).

**Generation Z** refers to people born between 1990 – 2000, i.e. pupils currently at lower and upper secondary schools and universities. Computers and the Internet became common in households in their childhood, they had the chance to *play computer games.* Šrahůlková (2013) states that 88% pf children claim the "enjoy" computers in general, 72% claim they like computer games.

Researchers speak of this generation's bond to digital environment, both in their free time and in education. This generation prefers computers to books (Posnick-Goodwin, 2010).

Sociologists describe this generation as egocentric individualities more focused on consumption than their predecessors used to be. At the same time the individuals are very creative, they can cooperate with each other and they like sharing the process of achieving a result, especially in electronic environment (Posnick-Goodwin, 2010). This generation is also characterised by a decline in science literacy (White Wolf Consulting, 2009).

**Generation Alpha** refers to individuals born after 2010. This means they are preschool children or children just entering primary schools. They were born into households equipped with computers, Internet, iPhones, iPads and they are surrounded by a number of interesting applications developed specifically for this age group as well as for their parents who also spend their free time playing computer games or on social networks. This generation spent much less time playing outside, in the streets or in the forests than their parents or grandparents. Family trips are becoming rare. Children from generation Alpha are often afraid of animals or they have very romantic ideas about them and love them all without any respect to their basic needs (welfare). Some of these children are even afraid of trees and woods (Jančaříková, 2015). Their bond to electronic digital environment and new technologies is even stronger than in generation Z (specialists sometimes speak of *dependence*). If they hear the word "mouse", they think of a computer mouse, not an animal. The prognosticators say that children from generation Alpha when they grow older will not respect the teacher (authorities at work), they will prefer sedentary jobs and home office, will be very good collaborators and will be even more creative (White Wolf Consulting, 2009, Posnick-Goodwin, 2010).

## 3.4 Classification of models according to the level of abstraction

With respect to the relationship between a model and a real object we can classify models in a broader sense for didactical purposes according to the level of abstraction that is needed to grasp them (adapted according to Harrison and Treagust, 2000) as follows:

- models of easily accessible objects
- models that allow pupils to see, observe, "feel" objects that are usually not accessible
- models that require abstraction
- models that represent theoretical knowledge; work with them requires not only abstraction but also relativism

### *3.4.1 Models of easily accessible objects*

These are models representing animals, plants and other products of nature, objects that children can see in vivo (e.g. models of earthworms, ants, flowers, common Czech mushrooms etc.). Models should first be the same size as real objects, later they can differ in size, can be enlarged if the observed object is too small (ant, flower) or reduced if the observed object is too big (e.g. giraffe). In fact, plush, plastic or wooden toys are also models if they are faithful representations of products of nature.

### *3.4.2 Models that allow pupils to see, observe, "feel" objects that are usually not accessible*

These are models of products of nature, animals and plants or their parts, common objects that cannot be manipulated in real life for various reasons, are accessible with difficulty or completely inaccessible (at least to young learners), or models that allow manipulation impossible with real objects.

An example may be a model of an anthill that shows a section through this anthill and allows pupils to observe what is inside without actually destroying it.

*3.4.3 Models that require abstraction*

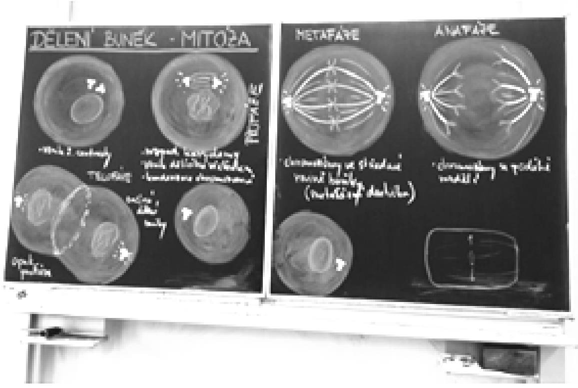


**Figure 5:** Schema of mitosis, Waldorf lyceum in Prague (Svobodová, 2016)

These are models of objects that are inaccessible to most people, e.g. the above mentioned model of a DNA double helix or models of cells or processes going on in a cell (mitosis). Pupils should be expected to work with models requiring abstraction only after thorough training, i.e. after consistent and methodical work with models from previous categories. However, this is often not the case in school practice.

*3.4.4 Models that represent theoretical knowledge; work with them requires not only abstraction but also relativism*


**Figure 6:** 3D Model of methanol (non-space filling and space filling) from the programme Wolfram|Alpha

A specific category are models representing newest theories that have not yet been empirically verified. An example of these are e.g. models of atoms or solar system as they were changing through history.

Models of this category are used to verify and improve theories on how a phenomenon works. A model of an atom is not meant to reflect its real shape but to highlight certain properties and relationships between the particles the atom consist of. In abstract models, the model always shows only some part of reality. Thus in history of natural sciences one can come across paradoxes in scientists' interpretations and the models they use; for example, light as waves versus light as particles (photons) (see Fosnot, 1996).

### 3.5 Work with models in natural sciences

PISA (Janík and Stuchlíková, 2015) defined work with models (in the broader sense, i.e. including two dimensional projections, computer simulations etc.) as one of the problematic areas in science education. We believe this to be caused by the fact that work with models cannot be grasped at once, it needs to be developed consistently and methodologically from very early ages. If a biology teacher projects a complex two-dimensional picture of a complex model (e.g. DNA double helix) without any previous work with models to their pupils, the teaching cannot be efficient and weaker pupils will get *completely lost* in the topic.

If a model is to be understood efficiently, it must be related to the real object it represents. This connection is called isomorphism (Slavík, 2004). It is thanks to isomorphism that pupils are able to understand a model and match its properties to the properties of real objects they are learning about. Our research in science education showed that Czech biology educators pay very little attention to work with models. Work with models is not a part of pre-service teacher training curricula and is not addressed by textbooks of science education (see e.g. Altmann, 1974, Pavlasová, 2014, Řehák, 1967). Thus it is not surprising that teachers pay little attention to the topic and sometimes even lead pupils astray, for example by referring to a model of a cell as to a cell.

We also discovered that very few teachers pay attention to a systematic development of abstract thinking needed for grasping models and their meaning. Work with models is paid more systematic attention in the curricula of alternative schools (Montessori, Waldorf lyceum) than in state schools. Much wider use of aids can be also come across in home schooling where parents sometimes borrow teaching aids from the above mentioned alternative schools. Moreover, introduction of new technologies often results in replacing collections of models of products of nature by electronic teaching materials.

**Example**
A teacher, when asked why he was getting rid of pictures and models of products of nature from his office, replied that they were no longer needed as the school purchased computers and a beamer. His lessons were now based on PowerPoint presentations and he was using the Internet. Old aids were too large and their maintenance too difficult.

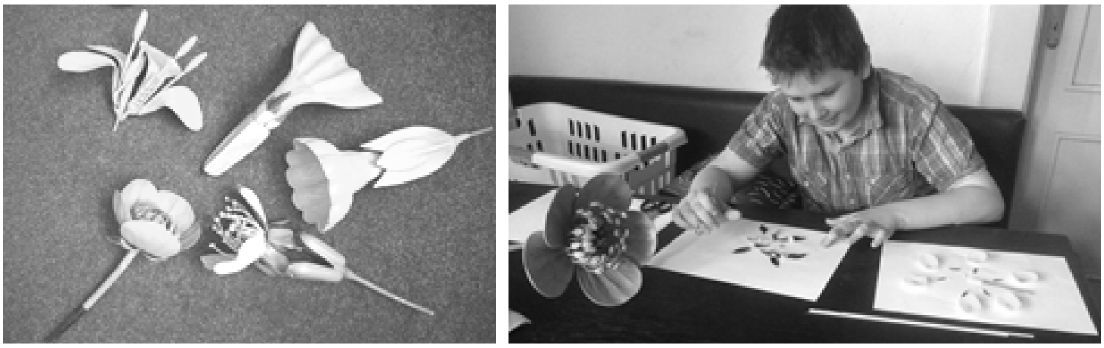

**Figure 7**: Models of flowers discarded in 2014 and a using of models by a 5th grader

This is wrong. Technical aids may help to learn knowledge of a topic, but one generally acknowledged didactical principle (Obst, 2006) states that the goal of an activity is not only knowledge but also other important learning objectives. These are appropriation of different methods of work, learning to work with different types of visualisation, getting experience of work with models, increase of environmental awareness, pleasure from discovery (Jančaříková, 2015). This implies that one of the objectives of education in natural sciences is development of the skill of isomorphism between a model and object, and of abstract thinking. To achieve this goal it is essential that pupils work with different types of visualisation. This must be done coherently and methodically. Physical models are an important step between real objects and their virtual visualization.

## 4. Guidelines to practice

### 4.1 Types of models

With respect to their purpose, models in natural sciences can be divided into two basic groups – models of objects and models of relationships and processes. Both these categories are often connected and it may not be possible to separate them, e.g. the model Solar system does not only give information about planets but also gives a lot of information on their relationships, possible positions and orbits. On a higher level, a model of an atom is not so much its physical visualization (enlargement) but more a schematic illustration of relationships between the particles that make up an atom.

#### *4.1.1 Models of objects*

Models of objects can be divided into three basic categories. These are:

- Illustrations
- 3D models
- Collections of products of nature

Computer technology only allows models of the first two categories. We must never forget the importance of work with real objects and be aware of both the advantages and disadvantages of computer models and absence of real objects in lessons.

**Illustrations**

Illustrations can be in colour or black and white. They also differ in size. They may require small or moderate degree of abstraction. Illustrations include drawings, paintings, photographs but also various types of projections.

**Figure 8**: Illustrations owned by the Faculty of Education Charles University, Czech republic

Although it may seem the best way to represent products of nature is to use a photograph, it is not true. A scientific drawing can highlight the properties that are essential for determination of a species and thus depict the species more accurately.

**3D models**

By 3D models we understand objects that represent a selected natural entity. The teacher should deliberately present models from various materials (wood, plastic, plush), of different colours and sizes to pupils. Developments in technologies brought about interactivity of many of the models. Thanks to technologies pupils can observe three dimensional objects either by the means of stereoscopic projections or thanks to augmented reality (see Jančařík, 2016).

**Figure 9**: 3D models used by authors

Figure 9 shows selected aids used by authors of this paper for development of abstract thinking and isomorphism in primary school pupils. Reduced models (models of solar system, of dinosaur and elephant), enlarged models (models of the life cycle of a ladybird, ant, stag-beetle, mosquito), models in the same size (models of a bat, germination). Also representation of hatching and growing of a duck. On the second photo is old 3D dynamic model of baby birth.

**Products of nature and natural materials**

Mounts are a specific kind of 3D models in a broader sense. Mounts can be temporary or permanent. Permanent mounts are for example staffed animals and their parts (skeleton, leg with claws etc.), herbarium items and collections (entomological collections, collections of minerals and rocks etc.) When exploring real natural mounts pupils use other senses (e.g. touch) and gain experience they would never gain from modern technology.

**Figure 10**: Biology collection of the Department of biology and environmental studies at Charles University in Prague, Faculty of Education

### *4.1.2 Models of relationships and processes*

Similarly to models of objects, model of processes and relationships can be divided into categories as follows:

- Static schemas
- Dynamic schemas
- Interactive models

**Static schemas**

A static schema illustrates a relationship or a process a pupil is to learn. Static schemas require a high level of abstraction on the pupil's part as the progress of the process must be visualised by the pupil. On the other hand they allow us to describe and capture the main parts of a process and partially also the circumstances under which the process takes place. The internet provides an unlimited number of schemas describing processes and relationships.

**Dynamic schemas**

When using dynamic schemas, pupils may observe the course of a process (either directly or schematically). In case of dynamic schemas on computers the pupil can select which parts of the process will be displayed and can then observe the depiction of their course.

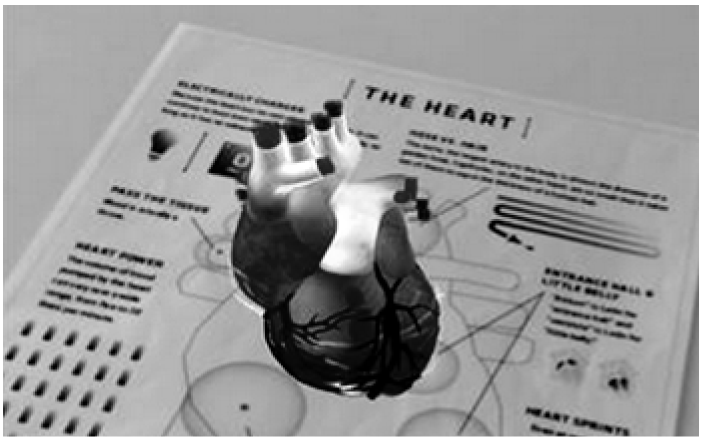


**Figure 11:** Human heart in the application Body 4D

Thanks to augmented reality used in the application Body 4D, pupils can view the activity of human heart, listen to heart beat, they can view it in different perspectives and at the same time choose one of its parts and select an activity of this part at the different phases of its activity.

**Interactive models**

Interactive models allow pupils not only to study the progress of an activity/process. Pupils can also influence the progress by changing various parameters. Interactive applications usually use mathematical models

describing individual phenomena and their relationships. One of the best known examples is the simulation of fox and rabbit population foxes on a given territory. Pupils can choose more than the initial number of animals. They can also change the parameters affecting their number (Breed rate, Death rate).
Tady vypadl ten ekologický model. Je to ok?

## 4.2 How models differ from real objects

Models are not real objects, they only represent them. Work with models always requires abstraction. The following text first presents basic differences between models and real objects. Then models are classified according to the level of abstraction that is needed for their understanding.

### *4.2.1 Reality versus model*

Models that pupils meet always differ from reality. When working with models we must be aware of these differences and address these differences when introducing models in lessons. The most common differences between models and reality are the following:

- Schematization
- Different dimensions
- Different duration of the process
- Lack of stimuli for sensory perception
- Lack of variability

### *4.2.2 Schematization*

Many models use schematization. Some schemas are notoriously known in our culture (e.g. a circle surrounded by lines = sun). Other schemas require education and their mastery is the sign of expertise in some discipline (e.g. symbols for men and women, symbols used to describe flower patterns and also graphs and diagrams, e.g. climographs).

### *4.2.3 Dimensions*

A human as an observer has their physiological dispositions. This means that too big organisms (solar system, whale or dinosaur) or too small organisms (microorganism) are hard to observe. Models are made to allow us get to know these too big or too small objects with more ease.

One of the key prerequisites for understanding work with models is abstraction of dimensions of the studied object – the pupil must be aware of the fact that a model of a cell is much larger than a real cell or that a model of an eye is much larger than a real eye. Optimally the pupil can represent the size of the real object.

### *4.2.4 Duration*


**Figure 12**: Representation of sound wave in the series Magic School Bus

Analogically also the time scale might be different in models of processes. The model may be faster (e.g. a model of soil erosion or a video of cell mitosis) or slower (e.g. a video of a running cheetah).

It is much harder to give pupils an idea of time duration of a process than of its dimensions. The progress of phenomena can be so fast or slow that a parallel imaginable to pupils does not exist. The figure shows an example from the series Magic School Bus where pupils observe propagation of sound waves using special glasses. In order to demonstrate that sound propagates as a wave, its movement is significantly slowed down while movement of people is not changed.

#### *4.2.5 Models do not provide complex stimuli for sensory perception*

One must always bear in mind that when working with models pupils are deprived of a significant part of perception that they would experience if they were in contact with and manipulating real objects. A living animal unlike its model has a unique smell, is warm and soft when touched, makes sounds and pupils may observe signs of its life (growth, excretion, ingestion etc.). Although some advanced applications for iPads and iPhones can simulate some signs of life (e.g. growth), they can never simulate all of them.

**Example**

A six year old David answered the question: “What is nature?” as follows: “I think animals. On our tablet we have sheep, cows and maybe we will have a dog and a cat. We also have wheat there. It grows in 5 minutes.”

#### *4.2.6 Lack of variability*

A substantial disadvantage of models is their lack of variability. Models usually represent the typical situation. But variability is common in nature (e.g. fingerprints of every person are unique, there are no two identical leaves etc.). Teachers should work with variability but they very often try to avoid it.

**Example**

7$^{th}$ graders were asked to bring a tulip flower to a biology practicum. They were observing it, mounting it and recording its petal pattern. One of the pupils discovered her tulip had only five stamina (usually it is 6) and informed the teacher about this. The teacher accused the pupil of having bought this “defective flower” deliberately to spoil the practicum. The pupil was asked to record a standard tulip flower according to a drawing on the board in her worksheet. The teacher failed to use the potential of the situation and failed to work with variability.

### 4.3 How to bring models into lessons

Work with models of this category and the ability to make them and improve them is in fact the long-term didactical objective of science education. Naturally not everybody is able to achieve the level of work with models that represent theories, to create them and look for their shortcomings. The goal of science educators as well as developers of applications is to maintain the number of scientists who have actually acquired this ability (PISA reports are very critical and speak of a potential decline in the number of people who have this ability) or to increase it (Jančaříková, 2015).

When creating teaching materials one should be aware of the fact that models always represent only a part of reality. If they are to be used properly, pupils must be taught how to work with them and how to distinguish between a model and the object or the process it represents. When creating teaching materials, the following three principles should be respected.

#### *4.3.1 Proceed from simpler to more difficult*

Models must be included in lessons gradually, starting from simple models and moving to the more abstract ones. It helps if the first models represent objects that pupils are familiar with. The use of these models is not motivated by introducing the object to pupils but by the effort to introduce pupils to differences between models and reality.

The principle of progressing from simpler to more difficult objects is more than relevant when using audio-visual technologies. Mangal (2008) states that selection of appropriate audio-visual aids in relation to the age group of students is very rare. Teachers often fail to realize which audio-visual aids are most suitable for young learners, grown-ups and higher grade students. One of the reasons why this might be so is that a number of teachers have minimal personal experience of appropriate use of technologies in education. They have not used these technologies at schools and very little attention is paid to it in teacher education.

The advantage of this approach is that pupils learn to work with models and gradually develop their competence for future work with models and for understanding even more complex and more abstract models.

#### *4.3.2 Showing the ratio*

If pupils are unaware of the differences between models and reality, teachers must pay attention to pointing out the differences between the depicted phenomena and reality. This puts high demands on the teacher. First of all, the teacher must understand what a model is, must be aware of the fact that a model is only an aid for description of reality (it is quite common that the teacher refers to the model of a cell as to a *cell*). The teacher should also know the level of their pupils' competence in work with models, should be able to estimate to what extent their pupils may grasp the new model. Also, the teacher must be able to assess how well their pupils cope with grasping the model.

#### *4.3.3 Example of good practice – Magic School Bus*

Ratio of dimensions is well shown in the series Magic School Bus. Dimensions are represented here by enlarging or making smaller the bus and subsequently comparing it to objects pupils are familiar with. In case the reduction exceeds pupils' imagination (e.g. to the level of cell), it is done in several steps.

#### *4.3.4 Problematic work with size of the model*

Work with the size of a model can become rather problematic in case of some applications that use augmented reality. The size of the depicted object in relation to real life objects depends on the user and does not have to correspond to reality. For this reason we do not consider use of these applications with very young learners as didactically correct.

**Figure 13**: Magic School Bus – Observing ants

**Figure 14:** Becky 3D Stereo Card

### 4.4 Learning outside of school

A wide range of teaching aids and materials discussed in this article are freely accessible and are used not only at schools but also in informal education outside school. Children get educated by TV and internet programmes, with educational toys and knowledge games, but also when working with apparatuses and devices (e.g. microscopes, astronomy binoculars, weather stations) they were given by their parents.

A stand-alone group we focus on in our research are home-schoolers in the Czech Republic. In the home-schooling community learners and their parents lend each other teaching aids and also share instruction on how to make them or share experience with their use. This exchange involves computer programmes and tips for educational programmes. It is much more common for home schoolers to have science "lessons" in the open. In comparison to school education home schoolers spend more time observing the surrounding world and recording their observations in longitudinal projects.

### 4.5 Computers and models

Thanks to the Internet and computer, documentaries and educational programmes about natural sciences are available to pupils without any limits. Thus pupils can observe behaviour of species in the wild that they would never meet under different circumstances. However, these observations can never fully replace direct contact with wildlife and nature. Children nowadays show symptoms of alienation from nature. That is why science education must include also activities in which children get the chance to build relationship to wildlife, to use all senses, i.e. also touch, smell and hearing. This is something that computer models still fail to provide.

#### *4.5.1 Dangers of use of technologies*

The use of modern technologies bears also other risks. The easy availability of materials may result in their overuse. Displaying too many audio-visual aids simultaneously in a single class can be very confusing for students and even for teachers as well. Concepts can overlap and can lead to misunderstanding and poor retention (Sampath, Pannneerselvam and Santhan, 1998).

Use of a model is not only in the hands of the author but also of the educator who works with it. A model is a model and cannot be taken as reality. However, developers of applications try to use names that evoke the idea that the applications present real animals, plants, nature. That can be very confusing, especially for young learners.

The teacher must never get the false impression that interactive materials are self-explanatory. Prasad warns that illustrativeness of materials does not guarantee they will be understood correctly. A teacher's explanation is essential if misunderstanding should be prevented. Otherwise instead of passing a concrete concept, the model will lead to misinformation (Prasad, 2005).

## 5. Conclusion

Development in natural sciences resulted in a situation when pupils come across computer simulations of organisms and their parts or processes that take place in them more and more often. This puts new demands already on very young learners. They must have the specific skill of abstraction and the ability to understand the relationship between the (most often virtually presented) model and reality.

Not enough attention has been paid to work with models in science education (not only in the Czech Republic). There is no thorough methodology of work with models and it is not included in pre-service teacher training deliberately.

The situation in which pupils and students are subjected to two dimensional models or objects in e-learning without actually seeing it with their own eyes needs consistent preparatory work with models of objects the learner are familiar with, can view and touch. The same must be done when preparing learners for work with three dimensional projections.

Undoubtedly a lot of attention will have to be paid to work with models. The ability to work with models has grown indispensable and its importance keeps growing. The goal of this paper is to start an expert debate on this issue.

Appropriate use of models in education is very beneficial. Audio-visual and interactive materials make the teaching-learning process more successful and interesting. Modern technologies allow pupils to get acquainted with natural objects that would otherwise be inaccessible.

An extensive area that needs further research and that has great potential for school practice is the area of interactive computer models that connect descriptive knowledge of studied objects to their activity and functions by placing them into larger contexts. 3D technologies, including augmented reality (e.g. 3D anatomic atlases), have significant potential in the field of education. This means the question of how to use these technologies efficiently remains topical.

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