ANIMATIONS AND SIMULATIONS AS LEARNING OBJECTS. MODELLING PROCESS AND QUALITY CRITERIA

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Abstract: Animations and simulations (A&S) are learning objects, developed to facilitate the understanding of an often quite complex reality. They are always based on conceptual models the developer(s) have of reality, which are reconstructed by the learner in his/her mind.
The development process of A&S can be described as a step-by-step-transformation of different models: From reality to a conceptual model, to a didactic model, to a design model, to a mental model of the learner. Visualisation facilitates the understanding of invisible processes and interactivity enables the students, to (re-)construct the conceptual model. Didactic design puts the focus on the learner's activities: to reconstruct, to interpret, to experiment, to predict, to control, to play, to create, to evaluate. Thus, animations and simulations touch all levels in the taxonomy of learning objectives.
In this paper we describe basic considerations of A&S as learning objects and follow the modelling process from a first concept of reality to the completed interactive model. A set of quality criteria for A&S is defined. We discuss these criteria by using different types of A&S as examples from the fields of natural sciences and computer science.

1. INTRODUCTION

Animations and simulations (A&S) are attractive learning material and are usually esteemed by students. Developing high quality A&S can be facilitated with a set of quality criteria which can be used during the development process as well as for the evaluation of existing A&S. In our experience it is important to support the step from a conceptual model to the didactic model, as this lays the ground for the mental models users will develop on its basis.

2. ANIMATIONS AND SIMULATIONS AS LEARNING OBJECTS

First we want to define some basic concepts. **Learning objects** have been defined in different ways. A broad definition of learning object has been formulated by the IEEE Learning Technology Standards Committee: "Learning Objects are defined here as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of technology supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments." (IEEE Learning Technology Standards Committee 2002). Based on this LTSC definition David Wiley has proposed a working definition. He defines a learning object as "any digital resource that can be reused to support learning." (Wiley 2001: 7).

Animations and simulations are learning objects, that implement models. A **model** is a representation of a complex system in a simplified form. It can be realised in a real 3-dimensional form, in a picture or graph, in a software, in a mathematical formula, in a text. In natural sciences and technique models have a long tradition. Good scientific models represent characteristic features of reality in a clear way as a logical, a mathematical, or a functional model. Real systems can only be analysed and described by models. An important motivation to construct a model is to predict the behaviour of a system. (Imboden & Koch, 2003: 7).

Whereas animations and simulations are learning objects, i.e. a piece of software, **mental models** are the representations of the model reconstructed by a learner. They "combine a schema or mental representation with a process for manipulating the information in the schema" (Merrill 2001: 12). A&S help to reconstruct models and provide interfaces to manipulate them. In this process **visualisation** plays a key role: "The process of communicating and sharing knowledge is linked to the presentation of knowledge - and the presentation of knowledge is - or could become - a central issue of design. […] visualisation means the transformation of generally invisible processes with the objective to facilitate and enhance understanding." (Bonsiepe 2000: 3). Model based learning is a constructive process with the focus on learners activity: to reconstruct, to interpret, to experiment, to predict, to control, to play, to create, to evaluate. A&S support all levels of learning objectives and **e-learning activities**. For natural sciences we proposed a typology of six categories of e-learning activities (Frischherz, Schönborn & Schulin 2003: 135).

We define an **animation** as a learning object, that allows the learner to observe, to reconstruct and to vary the presentation format of the object. And we define a **simulation** as a learning object, that allows the learner to construct an object or to modify the content of an object. The following table shows the characteristics of A&S (adapted from Schulmeister 2002: 194)

	animation	**simulation**
interactivity types	- to play, stop, repeat a film - to scale or rotate objects - to manipulate objects - choose or change representation format of the object	- put in data and observe consequences - visualise relations - vary parameters - create presentations - create contents
didactic functions	- information, illustration, instruction, motivation	- discovery, construction, reflection, discussion

Table 1: Characteristics of animations and simulations

3. THE MODELLING PROCESS

Conceptual modelling is a communicative and cognitive process. The creation of A&S can be described as a stepwise construction and transformation of models:

reality
↓
conceptual model
↓
didactic model
↓
design model
↓
mental model

Figure 1:The modelling process

The first step is the scientific analysis and creation of a **conceptual model**. In the next step the developer will reduce the cognitive complexity of the conceptual model and adapt it to the knowledge of the student. The developer will also design the learning activities according to the learning objectives. This **didactic model** will then be implemented in a software, which allows to interact with the model through an interface. The result of this process is a **design model**. Finally the learner reconstructs the scientific model in his mind as a **mental model**.

4. QUALITY CRITERIA

In accordance with the modelling process described in the last section, we can now set up quality criteria for good animations and simulations. The goal of these criteria is to assess the added value of this learning object. The main question is, whether the animation or the simulation supports the transformation process of a scientific model into a mental model.

a) Scientific standards: Whether or not the conceptual model is an adequate representation of reality, cannot be assessed here. If the conceptual model as such were to be assessed, scientific criteria such as correctness, verifiability, elegance etc. should be used.

b) Content selection and reduction: Normally scientific models need to be adapted to previous knowledge of the learners group. The developer has to select the most important elements and attributes of the scientific model and put the focus on them. The didactic quality of animations and simulation can only be judged respectively to a specific target group.

c) Learning activities: Another didactic task is to find learning activities according to the learning objectives. The student should know why he is doing what. For this learning objectives should be formulated explicitly and assignments should be formulated in a comprehensible form. Depending on the learning objectives different grades of interactivity can be provided. According to Schulmeister (2002: 193), interactivity means the active use of learning objects by the learner. The interactivity space represents all the possible learning activities provided in a learning object. Learning activities also need feedback from the learning material, from a tutor or from other students. Good learning material offers a wide interactivity space and meaningful feedback.

d) Media types: Digital learning material can be realised in multiple presentation formats: text, audio, photo, graphics, video, motion graphics… The combination of such presentation formats we call multimedia. Good learning material lets the student choose between different presentation formats according to his/her learning style and interests. Multimedia can enrich the learners experience and effect an immersion feeling well known from gaming.

e) Didactic context: Most A&S are embedded in a learning sequence and have contextual relations to previous and following learning objects. If learning objects are accessible as an isolated object these requirements should be made clear. In addition to the learning object, background information is useful, e.g. underlying formulas of a simulation or a help system for problem shooting.

f) Visualisation: Visualisation transforms generally invisible processes to facilitate understanding. In the field of learning, form always follows (didactic) function. Visualisation should represent main elements and relations in an adequate form and the inner logic of the image should enlighten their functions. Using metaphors is a useful means to transfer knowledge from one field to another.

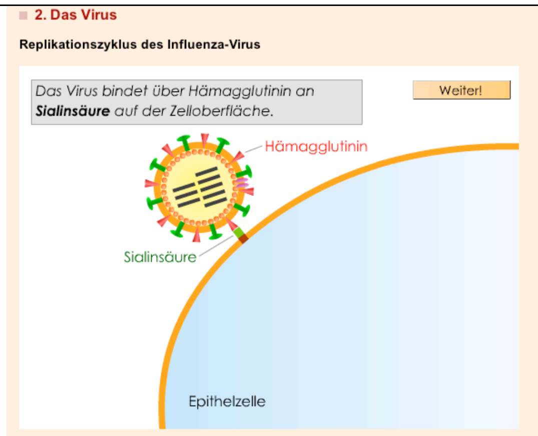
g) Usability: Usability is a quality attribute of learning objects that assesses how easy user interfaces are to use (Nielsen 2003). The interface should be self-explanatory and guide the attention of the learners. Key features are a clear navigation system and an intuitively usable control panel. In addition classical usability criteria for web pages can also be applied to learning objects: download time, cross-browser functionality, font type, font size, contrast…

h) Aesthetic quality: Aesthetic quality is perhaps the most subjective criteria in our list. Nevertheless it is an important one. Where the motto of usability is "KISS" (Keep It Simple and Stupid), the motto of design is "MAYA" (Most Advanced Yet Acceptable). The developer has to find the best level of innovation appropriate to the aesthetic feelings of the learners.

5. Examples From natural and Technical Sciences

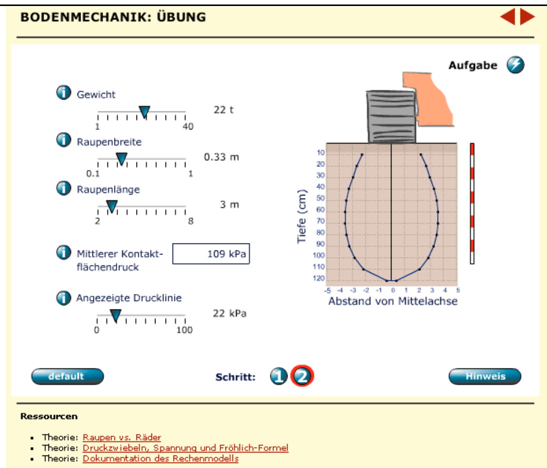
The following four examples are an attempt to show to what kind of results can be expected if our set of quality criteria is applied to real world examples.

5.1. Pharmasquare: Descriptive animation on the replication of the influenza virus (pharmaceutical science)

Simple descriptive animation from a sequence on the influenza virus. To be used as preparation for a lecture in a blended learning setting. Target group: students of pharmaceutical science.	
Added value: Low, compared to a figure with the same items.	
+ good embedding in learning sequence + good usability + pleasing design	
- low interactivity: Just click "continue" and "restart" - does not allow to explore different options/views - no zoom in / zoom out function	

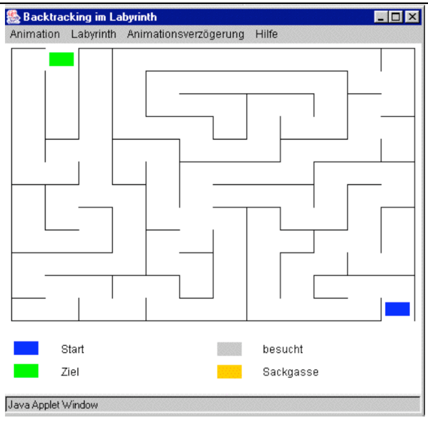
Comment: This first example already shows that our criteria must be used in a flexible way. For example, a "wide interactivity space" and a "meaningful feedback" by the animation may not be useful in this blended learning setting, where the students will meet their professor afterwards and where the only goal is to "pep-up" the existing diagram with some motion.

5.2. Do-It-Your-Soil: Simulation model on soil compaction (soil science)

Simulation from a sequence on soil compaction by heavy machinery. Objective: visualisation of pressure transmission into the soil. In two steps, the user can play with a set of machinery and with their weight, track length and track width. Target group: Advanced students of soil science.	
Added value: Medium to high. Visual feedback to experiments with different parameters.	
+ clear learning objectives and assignments + simple, but effective visualisation of a complex formula (Fröhlich formula) + good usability	
- rather low aesthetic quality - may be still too complex for some students	

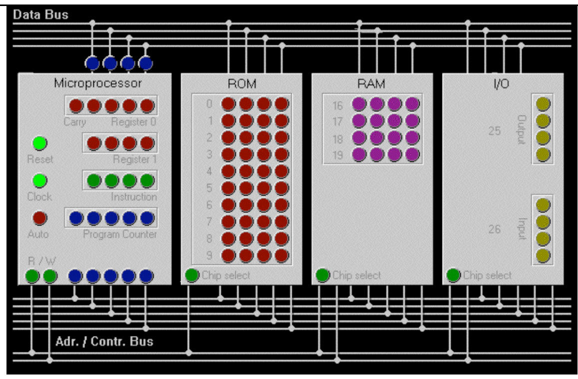
Comment: A classical example for the usefulness of simulations. Understanding the underlying Fröhlich formula would require quite some mathematical skills, whereas its model allows to intuitively understand the so called "pressure bulbs" right away. The model is still a simplification in that it does not display several pressure isobars at a time.

5.3. EducETH: Animation on the backtracking algorithm (computer science)

Descriptive animation on the backtracking algorithm in a labyrinth. Example used in a lecture on "Heuristics of backtracking". Target group: Students of computer science at a University of Applied Science	
Added value: good visualisation how the intuitive process of backtracking can be formalised	
+ simple, but effective visualisation of the backtracking algorithm + reusable learning object	
- low interactivity (animation can't be started from within its window and can't be stopped) - rather low aesthetic quality	

Comment: This Java based animation gives a direct impression what backtracking in computer science is about. This example comes closest to being an isolated learning object because it is not embedded in any learning sequence and is bare of all kinds of navigation. On the other hand this feature can also be considered a weakness of this example.

5.4. HTA/HSW Luzern: A simulation of a 4-bit demo computer (computer science)

Simulation and visualisation of the processes in a simple microprocessor. Every step can be tracked. Target group: students of computer science at the University of Applied Science of Central Switzerland.	
Added value: High. Students can perform own programming experiments on a basic level and observe data flow	
+ effective didactic reduction on a minimal set of components + high interactivity: definable functionality	
- rather complex user interface - needs additional lecture for usage - problems on Macintosh platforms	

Comment: This example fulfils most of our criteria for a good simulation. Content and functionality of the model can be defined freely by the students. Different solutions to programming problems are possible. The effect of the student’s activities can be followed in the animated graphic and used subsequently in an open discussion for “communication and reflection”. The complexity of the user interface and of the underlying model may pose a problem to the users.

6. Conclusion

Our search for a set of criteria has shown that didactic aspects are rather important for the development of good animations and simulations. In this regard, teachers - which are always trained in didactics - would be the natural authors of good A&S. In contrast to that, almost all examples for A&S we know have been developed by computer specialists. Also, they often are individually developed items. In reality, it is a long way from a conceptual model to the completed A&S. Several people may be involved, e.g., the author, a didactic consultant, a programmer and a designer. This makes the development of A&S tedious and costly. In our view there is a clear lack of a programming framework that would allow people that are not programmers (e.g., teachers, students) to develop A&S. Ideally, such a framework would allow to develop web based A&S. We think, it should be xml-based, open source and implemented either in Java or Flash. We would be happy to use it.

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8. Examples

Extended link list of animations and simulations
http://www.didanet.ch/pages/animation_simulation.htm

Do-It-Your-Soil: Soil mechanics.
http://www.armadillo-media.ch/swf/soil_compaction/soil_compaction.html

Educeth: Backtracking.
http://www.educeth.ch/informatik/vortraege/backtracking/demos.html

HTA/HSW Luzern: 4Bit-Democomputer.
http://www.hsw.fhz.ch/doz/pfischer/html/holzi_applet/democomp.html (Windows only)

Pharmasquare: Replication cycle of the influenza virus.
http://www.pharmasquare.org/newpage/Grippe/Grippe/Inhalt.html