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"Multicoding and Interactivity with Computer Visualizations

Multicoding, i. e. using various kinds of representation, can promote flexible thinking. Especially offering different visuals can bridge the gap between theory and application and support understanding what is discussed in lessons. In addition interactivity can promote a deeper processing. There are various guidelines that can be derived from psychological findings. Examples that we designed according to those rules are a virtual camera, a simulation of thermal and mechanical waves, and further applications.
This paper is a short glance at theory and corresponding applications.

The substructure of this paper reflects the following aspects:

- Why (and how) is it helpful to use multiple representations?
- What is the meaning of cognitive flexibility in this context?
- Giving an adequate feedback is important for interactive learning. Three kinds of feedback in multimedia applications are distinguished.
- Even self determined learning needs guidance and help. This will be the fourth aspect to come back again to multicoding of knowledge.

1. Multicoding

Learning and problem solving in physics make extensive use of various representations. Graphs, illustrations, different diagrams and symbol systems are used (see fig. 1 for some examples).

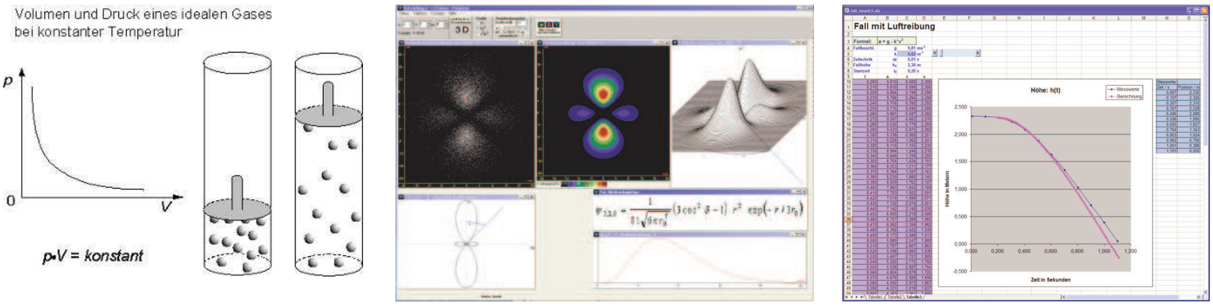


Fig. 1: Examples for multicoding of information.

One possibility is to connect a realistic view with the underlying theoretical background. This is also the underlying intention of the applet "virtual camera" (see fig. 2).

- You can, of cause, shoot pictures and see the results immediately (what is also possible with a digital camera),
- change settings (what is not so easy with automatic cameras),
- however, the most important thing is, that you can switch to a physics model view, and work with this representation (e. g. change the aperture, see what this means and study the consequences). So you can use different kinds of representation and switch between them.

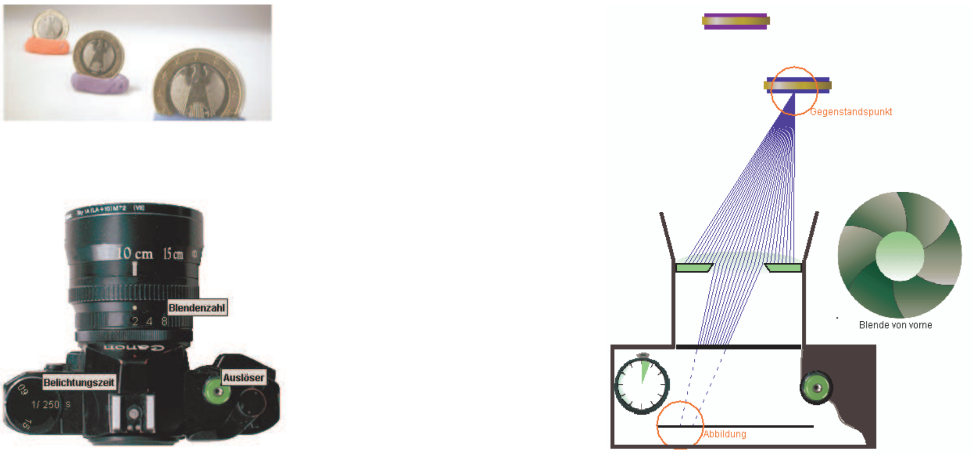


Fig. 2: Virtual camera with different modes of representation.

This already leads us to the ability of switching between different views – better between different cognitive representations. Often, this is useful in problem solving processes, and it is also important for a better understanding of different aspects in science.

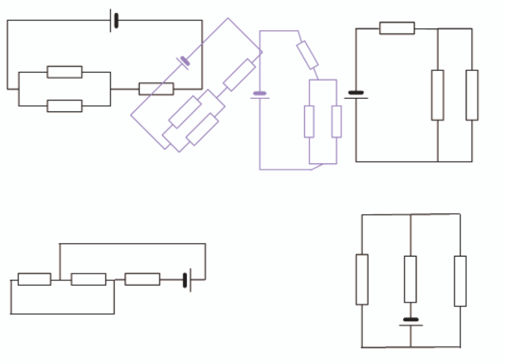
2. Cognitive flexibility

In this context the term cognitive flexibility points to an important ability: Cognitive flexibility is the ability to select a knowledge representation that is well suited to a given problem (see Spiro 1988, 1992).

In physics this comprises the capability to use different symbol systems. But also within the scope of one symbol system cognitive flexibility is needed (see fig. 3). One example, I appreciate very much, comes from Herman Härtel already from the 1990th. The electric current circuits in fig. 3 are equivalent, however their topology differs. By running the animation according to figure 3 it is shown that the circuits are equivalent. I use another example in my lecture, showing the equivalence of two transistor circuits. The slider is integrated in this application because of two reasons. We learned about that in an empirical study:

a) If you miss or don't catch a detail in simple animations the information is gone, and you have to repeat the whole animation. (Animations offer short-living information, and you can't go a step backwards.)

b) In simple animations the user is condemned to be a passive viewer. You can't control the situation (what is an important psychological aspect).



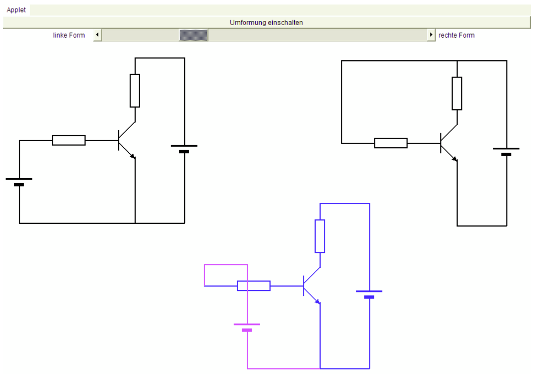


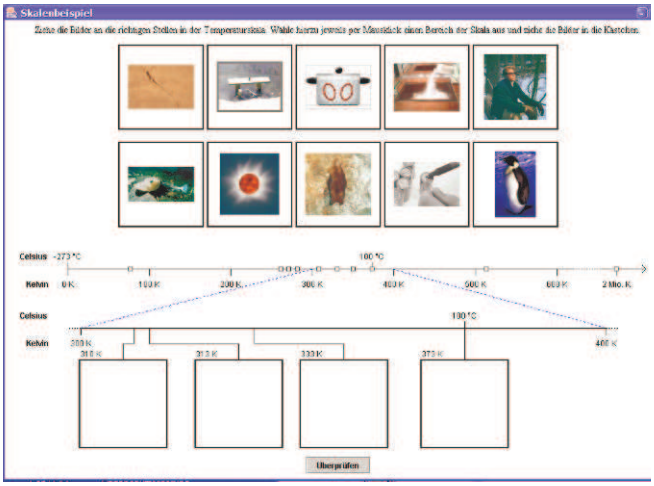
Fig. 3 and 4: Pictures from applications to show the equivalence of electric circuits.

3. Three kinds of feedback in interactive computer applications

Learning theories more and more emphasize active learning and self-pacing in learning situations. Herewith, adequate and individual feedbacks are considered as a fundamental prerequisite. Computers offer remarkable advantages for interactive learning. We applied three different categories of feedback that are made possible by multimedia:

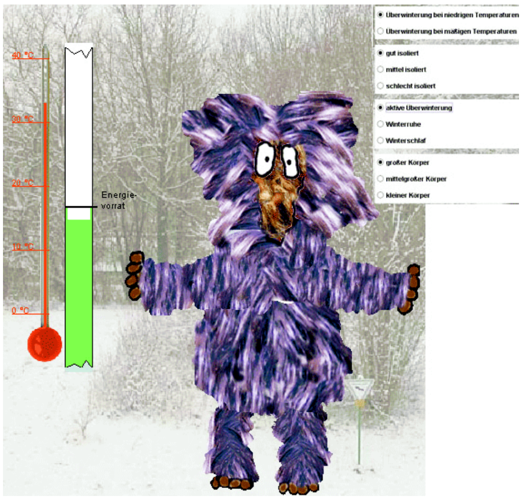
a) A simple but context dependent "*right or wrong*" (regarding the answer of a question)
b) A more sophisticated feedback that considers the results of decisions: "*win or loose*"
c) An inherent feedback on activities. Every action causes a specific outcome.

Corresponding applications are shown in figures 5, 6, 7.



Ziehe die Bilder an die richtigen Stellen in der Temperaturskala. Wähle hierzu jeweils per Mausklick einen Bereich der Skala aus und ziehe die Bilder in die Kästchen.

Fig. 5: Find out the right temperature that specifies the situation in the pictures. The feedback is "right or wrong".



● Überwinterung bei niedrigen Temperaturen
○ Überwinterung bei mäßigen Temperaturen

● gut isoliert
○ mittel isoliert
○ schlecht isoliert

● aktive Überwinterung
○ Winterruhe
○ Winterschlaf

● großer Körper
○ mittelgroßer Körper
○ kleiner Körper

Fig. 6: A virtual animal should survive a "digital winter". The feedback is "win or loose".

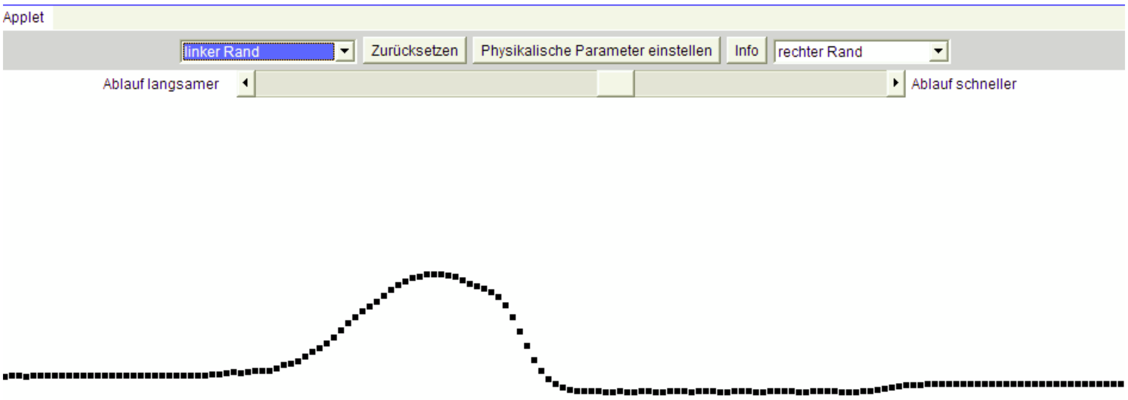


Fig. 7: A virtual wave machine. Moving the mouse leads to corresponding outcomes. You have to apply the right concept to get what you want (e. g. to produce standing waves). The feedback is given inherently connected with the results of the performed activities.

4. Guidance for goal directed and structured learning

Offering beautiful tools is not enough. Guidance to assist and structure the process of learning is needed. There is a short overlook over three methods we applied to give help.

The first method is to assign tasks to promote structured working. This was the intention of a phd student and he tried to find out, whether discovery learning is better for gifted learners and, vice versa, guided learning is better for weak students.

Statistics pointed into the right direction, however, the values were just below the level of significance. The reason, we suppose, is that we used school marks to distinguish between gifted or not so gifted students. We have to state, that school marks alone do not give enough information whether one is a good discovery learner or not. In fact, many pupils learn very well if they are strictly guided and learn specifically for school tests. Those pupils often were simply overstretched with discovery learning. Tasks have to be adaptable to learners' abilities. (See also Girwidz et al. 2006.)

The second strategy is the supplantation principle, which means that cognitive skills, a learner cannot perform, are illustrated by means of media.
Fig. 8 shows a simple example from science education. According to Bergmann's rule the size of penguin species grows with the falling temperature in their habitat. The smallest penguins live near the equator, the biggest near the South Pole. The reason is the relation between volume and surface. An analogous problem is to find the best form for a cylindrical tin with a maximum of volume but a small surface. A hint is given in the diagram on the right. If you do not see this at once you have the same problem as our 9th graders had. One step is to show the meaning of this diagram by linking it with realistic pictures (see fig. 9). The application illustrates the meaning of a point of the graph. (See also Vogel et. al, 2007 for more details.)

Fig. 8: Context volume and surface.

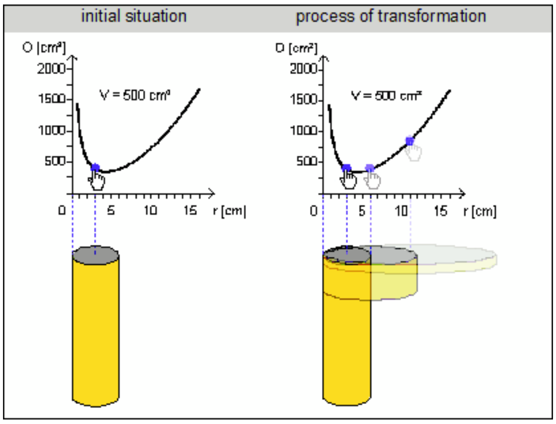


Fig. 9: Connecting a graph and its "message".

There are a lot more fields in physics for applying this principle. Figures 10 and 11 show two more examples, where this principle is integrated.

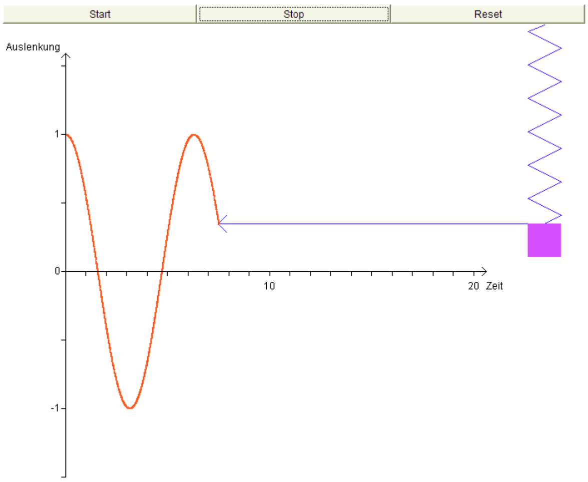


Fig. 10. Motion graph and the corresponding experiment.

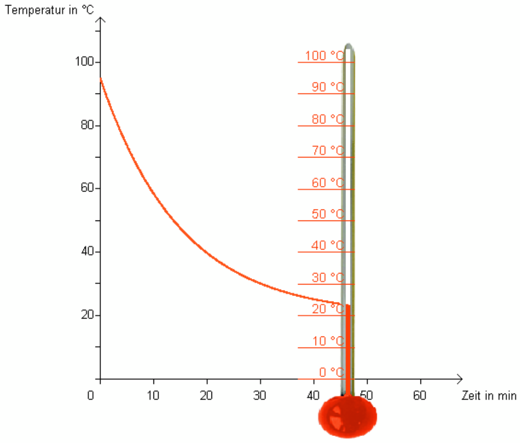


Fig. 11: Illustrating, what is shown in a graph.

You know the travelling of mechanical waves by experience. But what about the so called "thermal waves" that are created when you heat and cool a metal rod on one position?
This is illustrated in the following application, showing a totally different behaviour than mechanical waves – a kind of overdamped waves (see fig. 12).

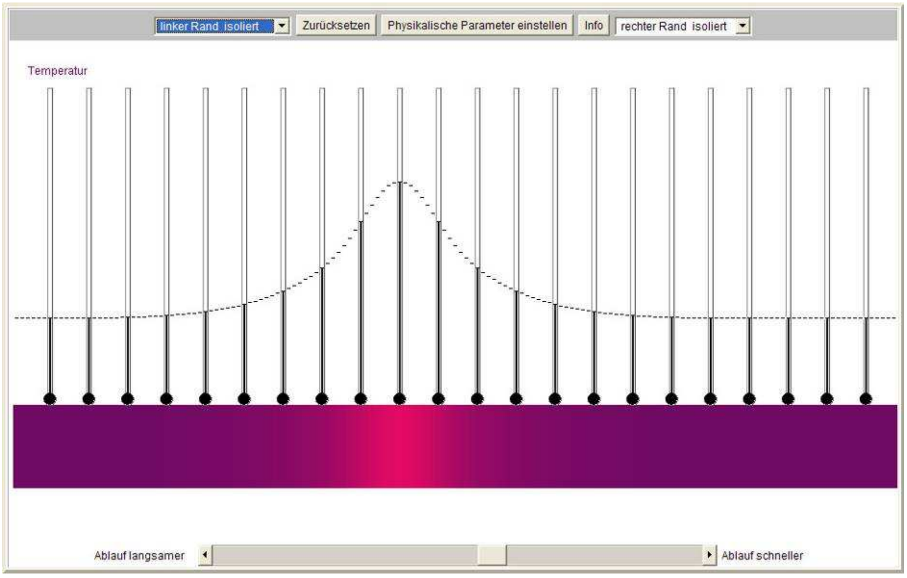


Fig. 12: Simulating the spread of thermal energy on a rod.

The third strategy is to assist goal directed learning by binding a program into an attractive information context.
As explained in many text books water waves are neither transversal nor longitudinal waves. The particles move in circles, having a phase shift between neighboring particles. But can you imagine how this leads to traveling waves? To illustrate this, the application in figure 13 was made.

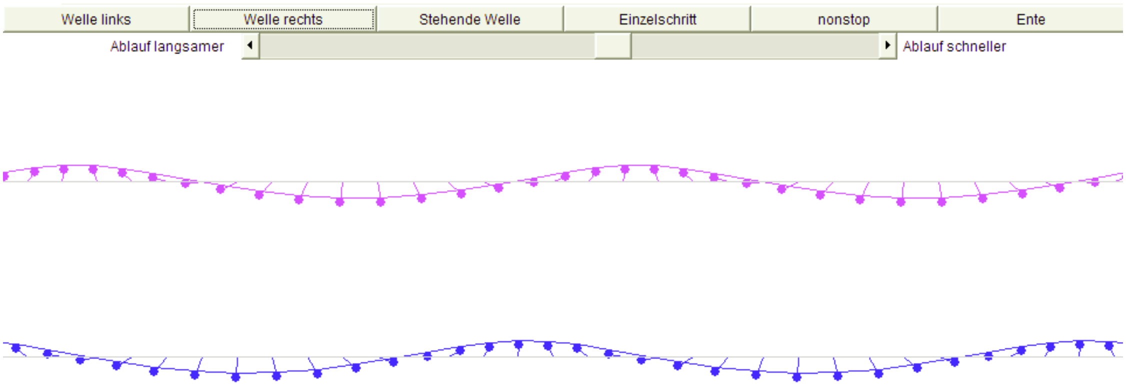


Fig. 13: Particles in a water wave moving in circles.

Our students accepted this, however according to an inquiry this information was not the best stimulus for learning. Then we wrapped the applet into an illustrating context from everyday life. Waves make water to go up and down. But, where does the material for the hill come from – where is the water gone, if there is a trough / a valley? There has to be a transport of material in horizontal direction (see fig 14).

Fig. 14 Water waves in a context.

You should watch the movement of a dug in reality – or in your bath tube. However in a bath tube you have to consider so called standing waves, and at a certain position the dug will only move vertically and at another position only horizontally (see fig. 15).

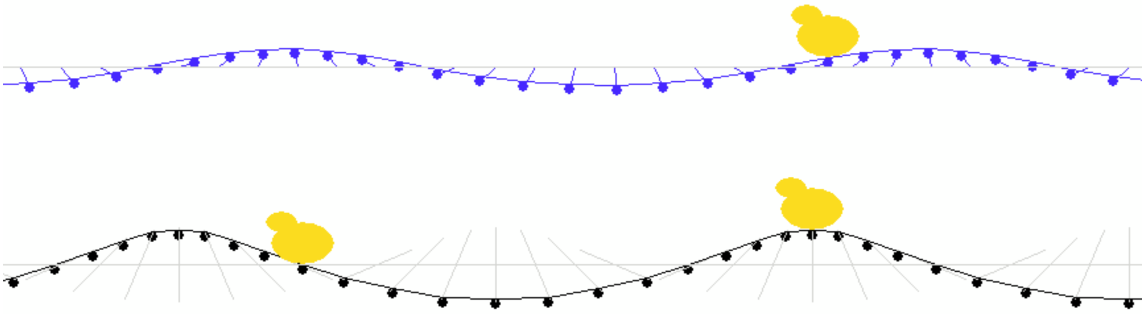


Fig. 15: Movement of dugs caused by water waves.

5. Connect computer applications with hands on activities.

If you replicate this described experiment in your bath tube this evening, this would be a successful integration of a computer demonstration into a multi-layered learning situation, and this is what we want.

(See also Girwidz et al. 2006a, 2006b for more details.)

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