

# Learning with a Virtual Camera – The Use of Multiple Representations for Learning

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## **Abstract**

Multicoding, i. e. using various kinds of representations, can foster flexible thinking. Especially offering different visuals can bridge the gap between theory and practice.

With this intention we developed a virtual camera, using multimedia to uncover basic physics of photography. A user can switch between a realistic view of a camera and a model, showing the physical components (lenses, aperture, image plain) and in particular rays of light. Different objects, including a moving pendulum, can be photographed. Exposure time and aperture have to be set according to the characteristics of an object. Pictures are presented immediately and the results can be understood by examining the model representation. Learning with the virtual camera has been studied empirically with 95 pupils (10th grade) and 35 teacher students. It was looked at learning outcomes in dependence on learners' abilities and the influence of narrowly or not so accurately described exercises. For statistical analysis t-tests and ANOVA were applied.

Results indicate that adjusted guidance is important, depending on learners' abilities, and an intensive and goal-oriented working with the computer program should be assured. Under these circumstances learning outcomes were found to be satisfactory for pupils as well as for students (on a higher level). Nevertheless one single lesson turned out to be too short to learn about complex dependencies and the virtual camera should be integrated into an overall concept.

Details will be outlined in the following sections, focusing on:

- \* multicoding and cognitive flexibility
- \* learning contents and the virtual camera as an aid to connect model and reality
- \* the empirical study and results.

## **Multicoding, mental models and cognitive flexibility**

Multicoding comprises the use of multiple representations for one topic. This facilitates focusing on special aspects in an adequate way, using the strength of specific descriptions or visualizations. Especially various illustrations can bridge the gap between theory and practice (see fig 1 and Girwidz et al. 2006a, b).

Mental models are analogous, pictorial representations, enabling the brain to simulate complex systems and to imagine how they might work under different settings. Classical examples are the functioning of a steam engine or an electric buzzer (De Kleer & Brown 1983). Mental models follow the assumption that human beings construct cognitive models of reality, reflecting aspects that are important for an individual. They

provide a reference frame for understanding new issues and offer a base for subsequent planning (Dutke, 1994). Multimedia may combine several types of presentation and thus also avoid overemphasizing superficial aspects by one specific representation.

For problem solving, the use of an adequate representation is important (already underlined by Larkin, 1983). The ability to alter from one representation to another in order to find an appropriate representation is a central aspect of cognitive flexibility.

"Cognitive flexibility" includes the ability to restructure existing knowledge according to the demands of a given situation (Spiro & Jehng, 1990). Thus, a knowledge ensemble can be tailored to the needs of a problem-solving situation, or can support learning and linking of new concepts (Spiro, Feltovich, Jacobson, & Coulson, 1992). Cognitive flexibility helps to apply knowledge under various conditions in an effective way.

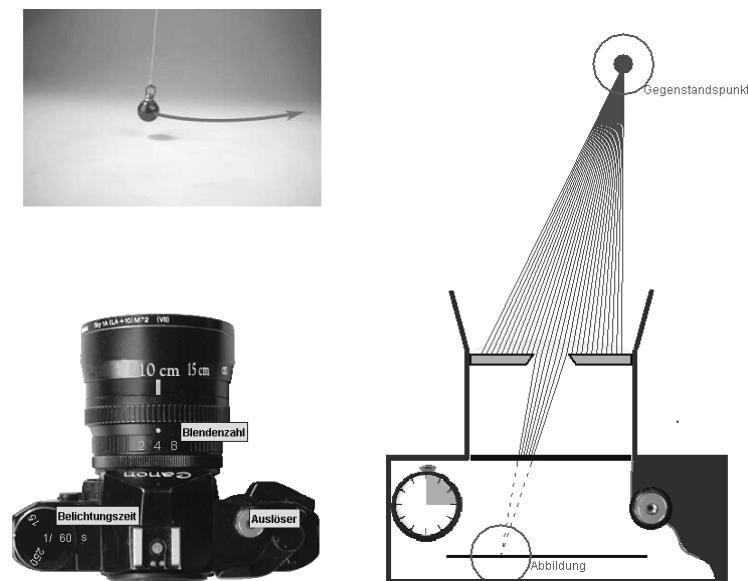


Fig. 1: Snap shots from the program "virtual camera", opposing a realistic view and a model.

To reach this, a learning environment is required, that offers corresponding features and possibilities to change from one representation to another.

This was a guide line for designing the "virtual camera", bringing together:

- a) objects to be photographed
- b) a superficial view of a camera and lifelike operating controls
- c) a physical model of a camera with components like lenses, aperture, and rays of light
- d) resultant pictures.

Altering between different instrument settings and analyzing corresponding results is made quick and easy. Interrelating settings and

results, theory and practice is intended. Beside the use of different representations, active learning is essential to foster applicability and to overcome inert knowledge. Students have to work with the material. This was supported by a workbook, also maintaining goal-directed learning.

### **Subject matter by examples**

How to shoot pictures of moving objects? Can motion be symbolized by fuzzy pictures?

When will background and foreground both be focused sharply? What are adequate settings for aperture and exposure time?

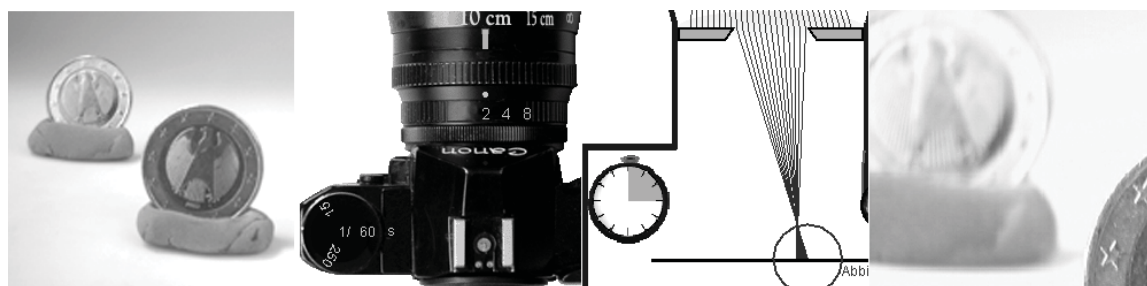


*Fig. 2: How to shoot moving objects?*



*Fig. 3: How to obtain depth of sharpness.*

Finding the right answer requires basic knowledge about optics. Furthermore different aspects have to be interrelated (relationships between aperture, exposure time, distance, lighting conditions, movement). A kind of multidimensional problem solving might become necessary, depending on the desired exposure.



*Fig. 4: Understanding depth of sharpness.*

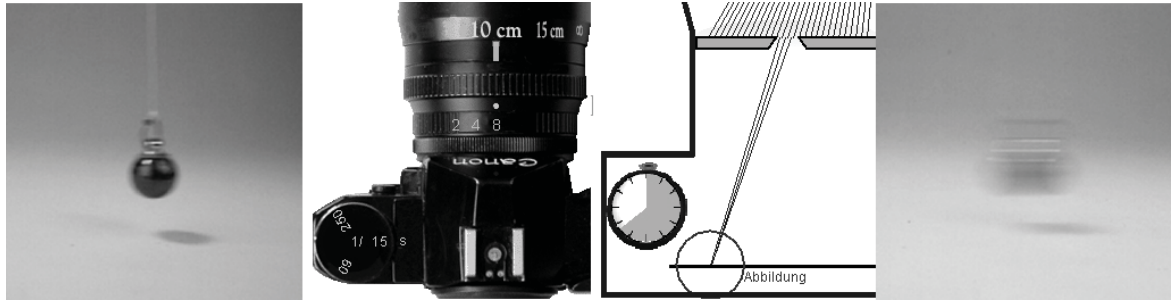


Fig. 5: Explaining fuzzy / wiggly pictures.

Changing and arranging different views is made easy in this computer application. Cross referencing model and reality is supported. For example, corresponding operating devices are located at the same position and can easily be identified in both representations. The virtual camera can be used or downloaded from the website: <http://www.film-phl.de> or [www.physikonline.net](http://www.physikonline.net).

### *A complex subject matter*

The topic is also interesting for studies about learning and problem solving, because multiple connections and relations have to be considered (see fig. 6). Thinking can step forward on different abstract levels, can include characteristics of the object, settings of the camera, the physical view and relate them to the photo-optical results.

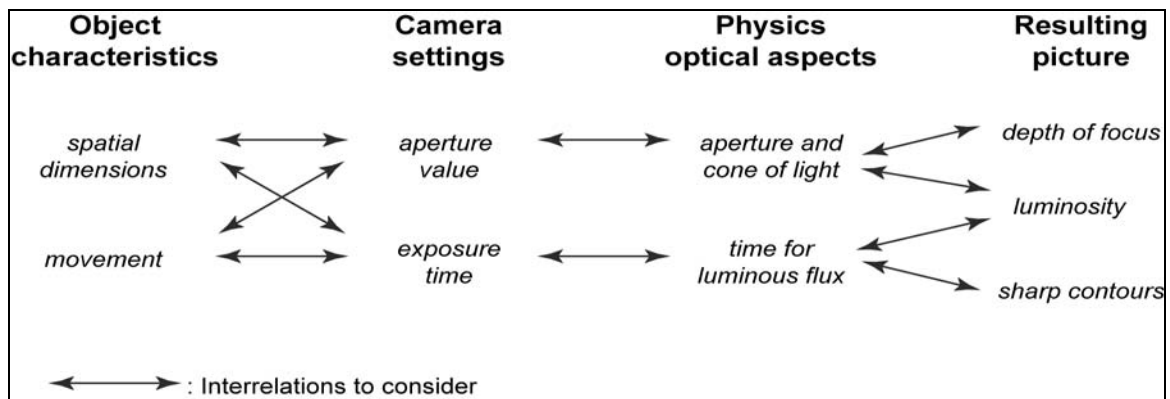


Fig. 6: Connections between different aspects.

### *Active learning*

In order to support active learning we used workbooks to assign tasks, to pose questions and to present problems which had to be solved. Two kinds of worksheets were developed: one to assist discovery learning, one to arrange a more guided learning. Nevertheless, cognitive and practical activities were impelled in both versions.

## **The empirical study**

How to use the camera in school lessons? Should students use the program self dependently for discovery learning or is guided learning better? Are open tasks adequate for brilliant students and, on the other hand, in-depth defined exercises better for not so gifted students? Does this computer application offer insights only for novices or is it also helpful for more experienced learners?

### ***Sample characteristics and procedure***

Participants in this study were 95 tenth graders at junior high school of intermediate abilities (in German: Realschule). They were pre-tested, focusing on their knowledge in photography three weeks before the main study. Furthermore, their achievement in physics and chemistry was assessed according to their school marks. The population was divided into two subgroups to compare different workbooks, one for discovery learning, the other one for more guided learning. On the average the students worked 31 minutes with the program and workbook. In addition also a group of 35 teacher students was tested.

### ***Testing***

The test contained 12 multiple choice items, leading to a maximum of 12 points. The questionnaire had to match two objectives. First, two levels of complexity should be tested: Questions referring to one modification only (e. g. changing of the aperture) set up the subscale “one-dimensional interrelationships”, and questions referring to more complex dependencies (e. g. how to obtain depth of sharpness) belonged to a subscale “complex connections”. Second, the questions should refer definitely to one form of representation (“model” or “superficial view”) and should indicate whether or not working with this representation was successful. (The questions were pre-tested with students and revised before usage.)

### ***Results referring to different subtopics***

Pre- and post-test as well as subscales were compared using t-tests (after checking normal distribution with Kolmogorov-Smirnov-test). Over all, there was a significant improvement ( $T=6,0$ ;  $p<0,001$ ). Questions requiring the work with the “model representation” were treated as good as questions that referred to the “realistic view”. However the improvement referred more or less exclusively to “one-dimensional questions”. Obviously a more complex understanding requires more time for learning. Table 1 presents an overview.

<i>n</i> = 95	All (max. = 12)		"one-dim. interrelations" (max. = 6)		"complex interrelations (max. = 6)		realistic view (max. = 5)		model representation (max. = 5)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
pre-test	3,2	1,8	1,5	1,1	1,8	1,3	1,2	0,9	1,5	1,1
post-test	4,6	2,2	2,8	1,4	1,8	1,2	1,8	1,1	2,1	1,4
difference	1,4	2,3	1,3	1,7	0,1	1,5	0,6	1,4	0,6	1,3
t-value	6,0		7,7		0,6		4,6		4,3	
p	< 0,001		< 0,001		0,52		< 0,001		< 0,001	

Tab. 1: Working with different representations.

### **Results - Interference between capability and kind of workbook?**

A 2x2-desing was applied to detect dependencies between different workbooks and the capability of learners. A median split, based on the school grades, divided students in two groups (strong learners and not so strong learners). An overview over the results is shown in table 2. There was no significant difference between strong and weak learners. Though strong learners did better with discovery learning, an interaction effect (according to ANOVA) was not significant.

<i>n</i> = 95	guided working	discovery learning	both together
strong learners	<i>n</i> = 23 <i>M</i> = 0,4; <i>SD</i> = 1,8	<i>n</i> = 21 <i>M</i> = 2,2; <i>SD</i> = 2,1	<i>n</i> = 44 <i>M</i> = 1,3; <i>SD</i> = 2,1
weak learners	<i>n</i> = 25 <i>M</i> = 1,4; <i>SD</i> = 2,3	<i>n</i> = 26 <i>M</i> = 1,7; <i>SD</i> = 2,5	<i>n</i> = 51 <i>M</i> = 1,5; <i>SD</i> = 2,4
all together	<i>n</i> = 48 <i>M</i> = 1,0; <i>SD</i> = 2,1	<i>n</i> = 47 <i>M</i> = 1,9; <i>SD</i> = 2,3	<i>n</i> = 95 <i>M</i> = 1,4; <i>SD</i> = 2,3

Tab. 2: Capability and working method.

Our interpretation is that common school grades do not determine absolutely whether guided learning or discovery learning is better for an individual. More factors have to be taken into account, especially some of those that are not included in normal school notes.

### ***Tenth graders and students***

The program was helpful for tenth graders but also for university students. Though they started on a higher knowledge level and had better pre-test values, their gains were in the same range (on a higher level). The conclusion is that the program does not only offer material for one single lesson and can be used at various levels.

### ***Outlook***

One single lesson turned out to be too short to learn about complex dependencies. The virtual camera should be integrated into an overall concept. Three or four lessons should be available, including discussions, examples from reality and also enclosing real experiments.

In order to find out more details about students' working, a new program version with a capture and replay tool will be implemented. So all activities can be logged, replayed and also categorized. Reactions on different hints will be studied.

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