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An innovative way for using computers in science teaching

Una manera innovadora para usar las computadoras en la enseñanza de la ciencia

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Abstract

The design of tools for teaching using new communication and information technologies (ICTs) is another important alternative to traditional methods to improve science education and to give students the opportunities of deep understanding. We present a study concerning the learning of physics (mechanics) while using the 'MODELSCREATOR' technology based learning environment. This learning environment makes possible the creation of models by pupils. From the analysis of answers collected from college pupils, in France, we show that the use of the software can facilitate the comparisons between aspects of reality, their conceptualization and their symbolic notations, provided that it intervenes jointly with the concrete realization of experiments.

Key words: *learning, sciences, representation, modelling, technology, learning environment.*

Resumen

El diseño de las herramientas para enseñar, que utilizan las nuevas tecnologías de la comunicación y de información (ICTs) es otra alternativa importante en los métodos tradicionales para mejorar la educación de la ciencia y para dar a los estudiantes la oportunidad de una comprensión profunda. Presentamos un estudio referente a aprender de la física (mecánica) mientras se usa la tecnología del MODELSCREATOR basado en un ambiente para aprender. Este ambiente para aprender hace posible la creación de modelos por los alumnos. Del análisis de las respuestas recogidas de alumnos de la universidad, en Francia, demostramos que el uso del software puede facilitar las comparaciones entre los aspectos de la realidad, su conceptualización y sus notaciones simbólicas, a condición que haya una intervención en común con la realización concreta de experimentos.

Palabras clave: *aprendizaje, ciencias, representación, modelización, tecnología educativa*

INTRODUCTION

The quality of science teaching is a very important aspect of education at the secondary level. The design of tools for teaching using new communication and information technologies (ICTs) is another important alternative to traditional methods to improve science education and to give students opportunities for deep understanding. But each active method should be applied by the teacher with systemic links with other methods and with main objectives of the course (ORLIK, 2006). The designers of educational software try to produce tools which imply other forms of work and other modes of regulation of the learning activities. The variety of tasks with which the pupils are confronted leads to a diversification of the mental activities that are required of them. The designers generally have the concern of allowing learners to work in an autonomous way. To learn how to learn, to develop higher cognitive capabilities, to facilitate and optimize learning (SWITZER, CALLAHAN & QUINN, 1999), to encourage the creation of knowledge. But what has happened in reality? In fact, a technology based learning environment exploits only part of the functionalities that the ICTs allow, due to the limits of the cognitive capabilities of the pupils, especially when they are young pupils. So, the learner is not able to manage several tasks if the environment is too complex. It thus proves necessary to conduct studies in order to evaluate which technology based learning environment really offers in the cognitive plan. Another essential problem is the appropriate representation of the central concepts and topics of the course, which can be done using modern systemic approaches (ORLIK, 2002).

The goal of this article is to present a new technology based learning environment intended for the teaching of sciences. We will analyze the uses that pupils can make of one of the functionalities of the new technology, which seems to us to be innovative.

Modelscreator

Modelscreator is a technology based learning environment (DIMITRACOPOULOU & KOMIS, 2005), designed to familiarize pupils with the steps of modelling (SMYRNAIOU & WEIL-BARAIS, 2005).

In examining the existing systems for modelling addressed to young students, we consider that they belong to three main categories. There are systems that support semi-quantitative reasoning: the WlinkIt and its previous prototypes IQON permitting the modelling of everyday situations, the system MODEL-IT dealing with ecosystems, as well the system SimQuest and its successor Co-Lab. Systems that impose algebraic reasoning are among others: Stella and Modellus. The modelling system Inspiration permits the creation of concept maps.

All the above-mentioned systems, possibly with the exception of SimQuest, support only one reasoning mode, while others are restricted to specific domains (such as Model-It).

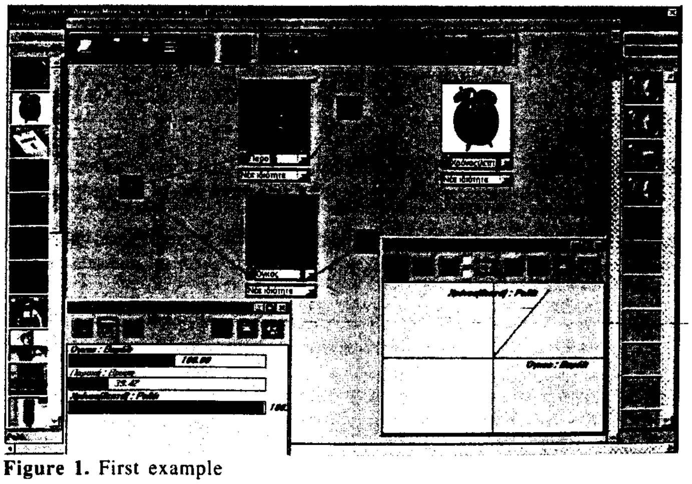

Figure 1. First example

Modelscreator offers the students a number of situations which are proposed for modelling, and permits the design, testing and validation of models (www.ecedu.upatras.gr/modelscreator/index_en.htm).

A pupil who wants to design a model must first determine the model's entities, located at the left of the screen, and the list of relations, which are located on the right side of the screen (see figure 1). For the building of models, Modelscreator offers concrete entities and abstract ones (which represent objects and concepts); and four categories of different relations to establish among the entities: a) qualitative logical relations (expressed by logical operators); b) qualitative semantic relations (able to produce concept maps).; c) semi-quantitative relations (relations in terms of variation of properties); d) quantitative simple algebraic relations (defined by arithmetic operators). Once the students have chosen the entities and the relations which represent the phenomenon he wants to simulate, Modelscreator offers them the chance to run a dynamic model. While it runs, a simulation of the modelled phenomenon appears in the area of entities' icons.

The following examples illustrate this (Dimitracopoulou *et al.*, 1999):

In the first example, shown in the previous figure, when the model runs, the student can see the water filling up the barrel for as long as the tap is turned on. In the relation between the barrel's volume and tap's rate of flow is an inverse analogy, it will result in the decrease of the water's volume in the barrel while the tap is on.

The second example (see figure 2) is a case of decision models. The student can see —in the icon related to the effect ('then')— the simulation of the decision's consequences (a boy will either cross the street safely or will have an accident).

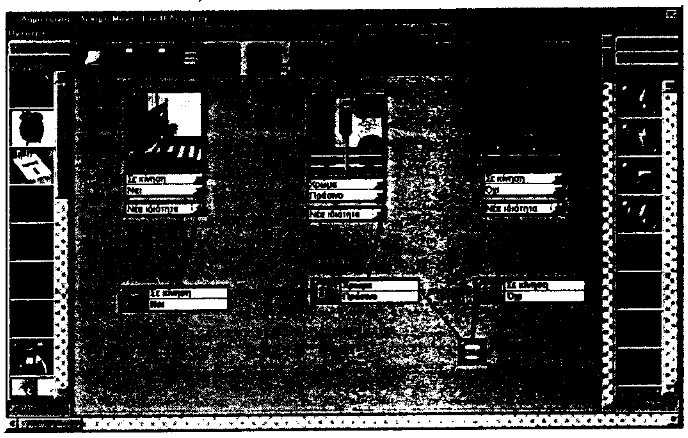

Figure 2. Second example.

DESCRIPTION OF THE STUDY

Hypothesis

We start from the hypothesis that the process of translation between representation systems allow students to 1) learn the meanings of symbols, which at the beginning may be opaque to them; 2) familiarize themselves with symbolic systems; 3) understand them; and 4) help them choose the most pertinent formalisms.

Objectives

If the software is used effectively, we can expect that the pupils who use it have a different approach to the physical systems with which they are confronted. If it is used to formalize the constitutive entities of the systems in terms of properties and relations between dimensions, the pupils should account for the transformations of the physical systems in a different way than the pupils who have only practical experiences with the physical systems.

The study was conducted in connection with a traditional situation studied in mechanics: the displacement of a vehicle on an inclined plane.

Problem

The problem suggested to the pupils is the following: "a car without an engine runs on a road which can have a more or less slope". A series of questions are posed to the pupils aiming at leading them to be interested in the relations between speed and mass, speed and angle of the road, speed and type of the road, speed and time of displacement.

Examples of the questions:

- Could you make it so that the car placed on the (horizontal?) paper surface is made to move without you having to touch it?
- Which are the factors that have an effect on the speed of the car?
- On which surface (concrete, frozen, etc.) does the car move faster? Explain your answer.
- A car rolls on an inclined road. Imagine that a second car, larger this time, moves on the same road. Which car will go down faster? Explain your answer.
- Can you say what is the relation between the speed of the vehicle and the duration of displacement?

The pupils have either a set of objects (of cars and supports), or the technology based learning environment.

DESCRIPTION OF MODELSCREATOR IMAGES

The screen of the computer presents the image of a car designed like an entity. We can describe it by his mass and his speed (called 'properties' in Modelscreator). The mass and the speed of the car can be modified. The modification of the mass is represented by three different sizes of cars. The modification of the speed is represented by an increase in the shading of the back of the car as we can note on the images reproduced in figure 3.

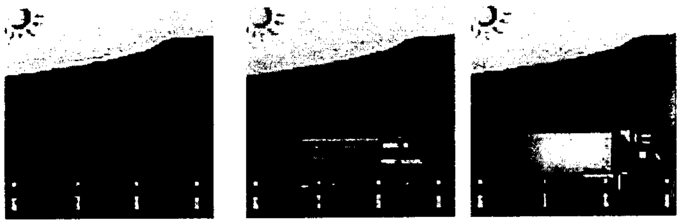

Figure 3. The representation of the modification of mass and speed

The other image (entity) represent a road which has two properties: angle and type of road (that corresponds for us to the coefficient of friction, but we did not use this term because it is unknown to college pupils to whom this task is addressed). The angle can take various values: the road can be horizontal or more or less tilted. The road can be icy, or wet, or made out of concrete or soil. (These images correspond to our representation of the coefficient of friction which is minimal (zero) in the case of icy road, maximum for the road of soil, the two other roads (wet and concrete) correspond to intermediate values, in the following order for the coefficient of friction (figure 4).

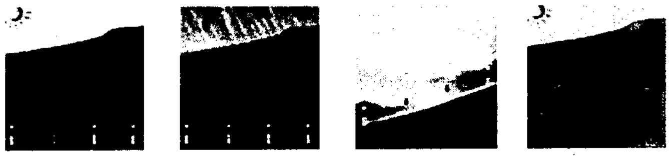

Figure 4. Representations for the modification of coefficient of friction and the angle

On the screen, the image of a clock also appears, representing the time necessary for the displacement of the car. Time has the status of the independent variable compared to the other properties, which are the dependent variables.

METHOD

We compared the descriptions and manipulations made by the pupils when they had material objects (various plastic cars and various plane surfaces: paper, plastic ...) to carry out the experiments and when they used the Modelscreator which makes it possible to model and simulate symbolically the experiments. In so far as we can make the assumption that working on the objects and symbolic notations can have reciprocal effects, we counterbalanced the order of the conditions: a group of pupils worked initially with the technology based learning environment, then with the objects, the other group made the reverse (objects, then learning environment).

We conducted interviews with 26 pupils of high school (in the USA) attending the classes of 8th (13-14 years old) and 9th (14 - 15 years old) located in the Paris area. The duration of each interview was 15 - 20 minutes. The pupils had volunteered to participate.

RESULTS

When the experiments are carried out with the computer

Pupils are invited to look on the screen at the dynamic images which correspond to the formalization. The following question was put: "according to what you saw, can you say which is the relation between the vehicle's speed and the angle of the inclined road?".

The answers are distributed in the following way: 20 pupils said that the car goes faster with a larger angle giving various explanations, 4 said that the car goes slower, 2 gave no conclusion on the speed but about the state of the road or evoke the acceleration.

These answers reveal that spontaneously the pupils focus themselves only on one property (mainly speed), sometimes making a mistake in the interpretation of the direction of the change in speed (4 out of 26 pupils), not expressing the covariation between the increase of the slope and that of speed.

When we ask them to choose the most appropriate symbolic _expression, the majority of pupils (17/25) choose the relation which expresses the covariation (↑↑). However other answers appear, often multiple (cf table 1).

The students can choose and determine the desirable relation between two entities among the available relations of the semi-quantitative relations: these relations are in terms of variation of properties' values and direction of this variation. In the current version, the student can use simple relations that correspond to simple algebraic relations which are common in mathematics and physics. Each relation is represented by a symbol. For instance, the relations of analogy or inverse analogy are expressed through the reasoning "If the one entity increases, the other one might increase, decrease, or remain unchanged" and are represented by special graphic symbols (↑↑,↑↓,↑-,↑↑, or ↑↓). For example: covariation (↑↑) means that as the slope increases, speed increases. The relation (↑-) means that as slope increases there is no change in speed and the relation (↑↑) means that a small increase in slope produces a large increase in speed.

Table 1
The relation between the vehicle's speed and the slope of the plan

	1st relation (↑↑)	2nd relation (↑↓)	2nd 3rd relations (↑↓)(↑↑)	1st 2nd 3rd relations (↑↑)(↑↓) (↑-)	4th relation (↑↑)	Total
13-14 years	8	3	1	0	0	12
14–15 years	9	2	0	1	1	11
Total	17	5	1	1	1	25

The verbal justifications of the pupils are of a different nature. They are discussed below and their distribution is presented in table 2. Some of the pupils gave two answers. For these reason the number of relations (25) is more than the number of the students (23).

- Expressions of a co variation (COVA) or a contra-variation (CONTRA)

For example, a 13-year old pupil said: "*...the slope, it increases and the car, it goes more quickly*" (COVA). The pupils who choose the relation of covariation use suitable linguistic forms. The pupils who do not produce in the linguistic plan these relational expressions made choices of semi-quantitative erroneous or multiple relations.

An erroneous answer can also come owing to the fact that the dynamic images are not perceived in the way the originators of these images expect. For example, a 14-year old pupil mentioned: "*The more the slope increases, the more the speed of the car decreases*". Another pupil explained that "*the more the car goes down, the more the road goes up*". (?) Another 14-year old considered that "*The more the inclination of the road ...the more the car goes quickly*" (CONTRA). Thus, these pupils were led to choose the 2nd relation in table 1.

Such observations stress the importance of the understanding of the relations in natural language. The assumption that one can advance is that if the pupil is not able to understand the transformations relationally, in natural language, s/he is unable to do it with formal systems.

- Evocation of properties (POBJ)

It is the case when the pupil evokes only one of the properties of the object, for example a 13-year old pupil said: "... *it is faster* " and he chose the 1st relation in table 1.

- Conceptualisation (CNST)

Some pupils conceptualized the situation in physical terms of sizes. For example, a 13-year old pupil explained: "*The car accelerates when it is on a slope...*" and he chose the 1st relation.

- Sequential description (DESC)

Certain pupils described the movement when the car goes up and when it goes down, like if the two elements of the image and of the icon represented successive states of the movement. For example a 14-year old pupil affirmed: "*the car goes down, it goes more quickly and when it goes up, it goes less quickly*". Another indicated that "*the road goes up (↑) and the car slows down (↓), remains at the same point*" and there he chose the second relation (↑↓). We find the strategy of sequential reading of the images and icons already described by other authors as constituting an obstacle for understanding the variational approach of the relations (Baillé & Maury, 1993; Janvier, 1998).

The comparison of the given justifications according to whether the software was used before or after the experimentation with the objects (cf tableau 2) underlines that the use of the variational expressions is more important when the pupils have experimented with the objects. The sequential treatment of the images and the icons is not very frequent (4 pupils out of 26) but it concerns especially the pupils who used the software without doing any practical activities previously.

This result shows that only half of the pupils can adequately process the data presented on the screen of the computer and that more of them can if previously they have handled the objects represented on the screen of the computer.

Table 2
Justifications of the choice of the relational semi-quantitative expressions between the slope and speed

Scool level / Categories	*ModelsCreator* (used first)		*ModelsCreator* (used second)		
	8th (13-14 years)	9rd (14 – 15 years)	8th (13-14 years)	9rd (14 – 15 years)	Nb answers
Co-variation (COVA)	1	2	4	6	13
Contra-variation (CONTRA)	1	1	0	1	3
Properties of the objects (POBJ)	0	3	2	0	5
Conceptualisation of the situation (CNST)	1	1	1	0	3
Sequential description (DESC)	3	0	0	1	4
Other answers	1	1	0	1	3
Number of pupils*	6	7	6	7	26

*Some of the pupils gave two answers. For these reason the number of answers (31) is more than the number of the students (26).

When 'real' experiments are carried out

When the pupils carried out the experiment, the following question was put to them: When the slope of the plane increases, what happens with speed? Explain your answer.

All the pupils, except one, answered that when the slope of the plane increases, speed increases too. Only one pupil (in fourth) said that it does not change: "*Bah! That does not change*".

I think quotation marks are more appropriate here: "*Bah! That does not change*".

The arguments advanced by the pupils were varied. They are discussed hereafter and their distribution is presented in table 3.

- Relation of covariation (COVA) between the slope and speed (more...more). For example, a 14-year old pupil affirmed: "*The more the slope increases, the more the speed, while going down, will also increase*" or of contra-variation (CONTRA): "*The more the slope is steep, the more... e, less the car* is retained".
- Evocation of an object property (the car or the surface) accompanied with a comparative term of the "steeper, larger, stronger" (POBJ). For example, a pupil a 13-year old pupil answered: "*It (speed) increases because it is steeper there...*".

- Putting a correspondence between the physical situation and its representation on the screen (CORR). For example, a 14-year old pupil who had already carried out the experiment with the software answered: *"it ... returns to the same question"*.
- Mobilization of a physical concept like acceleration, push (CNST). For examples: *"Bah, the car, it will go always downwards"*, "The car goes more quickly because *it has more time to accelerate. There is more space to accelerate"*.
- Notation of the type: it will go more quickly, the wheels turn more quickly etc. (NOTI). For example, *"It increases because the wheels... e... that involve ... the wheels turn more quickly"* (pupil of third).
- Expression of a feeling of normal or logical as *"it is normal, logical or it is obvious"* (OBVI). For example, a 13-year old pupil said: *"I do not know, it is obvious, that appears so obvious"*.

Half of the pupils (13 out of 26) justified by observation their prediction relating to speed according to the slope of the plane on which the car moves. This concerns in particular the pupils who had experimented with the objects. Those, who used Modelscreator, do not seem to apprehend the experiments in a singular way. They do not put in the correspondence with the experiment that they saw previously.

Table 3
Explanations of the relation between the slope and speed, if the pupils carry out the experiments with the material

School level Categories	*Experimentation with the objects after use of ModelsCreator*		*Experimentation with the objects before use of ModelsCreator*		
	8th (13-14 years)e	9rd (14 – 15 years)	8th (13-14 years)	9rd (14 – 15 years)	Nb Pupils
Covariation (COVA)	0	2	0	2	4
Contra-variation (CONTRA)	0	0	1	0	1
Properties of the objects (POBJ)	1	1	0	2	4
Put in correspondence (CORR)	2	0	0	0	2
Physical concept (CNST)	0	1	0	0	1
Notation (NOTI)	1	2	5	5	13
Obvious (OBVI)	1	0	1	0	2
Other answers	0	1	1	0	2
No explanation (NEXPL)	3	2	1	1	7
Number of pupils	6	7	6	7	26

CONCLUSIONS

If we compare the advanced explanations of the pupils according to whether they experimented with the objects and the technology based learning environment, it appears that the variational relational approach is much more frequent with the learning environment than with the objects (13 out of 26 in the first case, against 4 out of 26 in the second case). However, this approach appears especially when the pupils had experimented with the objects before the use of the technology based learning environment. These results obtained with a reduced number of pupils would need to be consolidated. Indeed, they draw the attention to the cognitive benefit of the use of the learning environment if it is preceded by an experimental activity with the relevant objects.

The results obtained confirm the hypothesis that Modelscreator constitutes a good tool to help pupils understand the transformations of the situations into relational terms. However, they draw the attention to the need of practical activities using the objects and the questions about them.

The limitation of the work presented is due to the conditions of data collection: individual interviews where we avoided bringing other information than that provided by the activities themselves, with the objects or the software. Future studies with small groups of pupils will make it possible to specify what can promote interactions between pupils.

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