

Bridging the Gap between Physical and Abstract Worlds: Capturing Observed Phenomena in Abstract Models through MODELLINGSPACE

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Abstract

Observation and understanding of real world activities and phenomena is a basis of inquiry and reasoning and subsequently building of scientific knowledge. This involves moving from the perception of real world phenomena to constructing and exploring qualitative and quantitative relations that hold among the main elements. The transition between the two phases is not always smooth for the learners involved. In this paper, we present tools and activities that attempt to bridge the gap between the physical world experience and the abstract modeling and reasoning phase. Firstly, we discuss a modeling approach and the various representations involved. Then, we present the Video2Frames tool of ModellingSpace which is proposed to be used in order to create educational material by allowing the creation of abstract entities from video recordings of phenomena. Next an example of creation of educational material, using this approach is presented and discussed.

1. Introduction

Building and exploration of models by learners is increasingly recognized as a potentially powerful technique conducive to learning [1]. Modeling software tools include direct manipulation spaces in which learners can build and explore executable models of phenomena occurring in disciplines like physics, biology or environmental science. Modeling activities involve several cognitive processes. Students during the creation or exploration of a model represent, explain, communicate and support with arguments their ideas. They also control, predict and conceive concepts and use reasoning. All these cognitive processes can lead to understanding of concepts and phenomena instead of simple memorization. Modeling

activities can enhance the learning process because, during the construction of a model, students express their ideas and get conscious about them. This awareness is the first step for cognitive change. Models also allow abstract ideas to take a tangible form which are easier to be manipulated by students [3].

The representations used in these environments may vary. In [2] a study was conducted on the relation between the representations used in modeling environments and their learning impact. For instance graphical or textual representations may be used to express the relations in a model. In [2] it was discussed that choosing a graphical view means emphasizing the qualitative model characteristics, while choosing text implies a focus on the quantitative details of the relations. A major concern of teachers or developers of educational modeling activities is the selection of adequate representations for the variables (entities) and their relations, the building blocks of models.

In terms of the *relations* between the variables of a model, typical representations include qualitative relations, usually in verbal form to be used in concept maps, quantitative mathematical relations, used in environments like *Interactive Physics*, *Modellus* etc., while a third case between these two involves semi-quantitative relations, which express mathematical ideas while not using mathematical functions. In this case the representations used for the relations are of graphical form, expressing in iconic way concepts like “proportional”, or “inverse proportional” relations. Many contemporary modeling environments support a combination of these representations in order to support transition from one representation to the other. Examples of such modeling environments are ModelsCreator [3] and ModellingSpace [4]. The modeling objects in these environments for quantitative or semi-quantitative models are objects

that behave according to the value of the variable that they represent in the model.

An example of this kind of representation, from ModellingSpace, is shown in Figure 1. The concept of volume is represented through a real-world object (a barrel filled with water) and a property of this object (volume of fluid). Two different representations for expressing the states *full* and *empty* are shown. These can be further expressed through numeric values of volume of fluid, measured in liters. The student can manipulate the state of the object, once inserted in the modeling environment, using the sliding bar under the image.



Figure 1: A ModellingSpace object, The variable volume of fluid takes the values “small” and “big”

A model can be built by using this kind of representation of variables and by connecting them with different types of relationships. A relationship between two concepts, may be established using a semi-quantitative proportional relation (increases-increases), as shown in figure 2 for the variables *Duration* and *Temperature* in a Physics experiment. Through this a cause-effect relation between the two variables can be modeled and explored. After establishing this relation, the student can manipulate through the sliding bar the independent concept but not the dependent one, which is affected through the established relation.

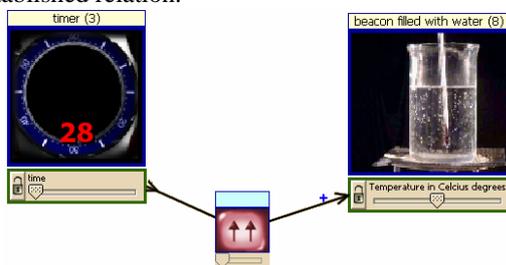


Figure 2: An example of relationship between entities

The models of this nature can increase in complexity. The users are able to explore the model by moving the slider of a property of the entity or by

running the model. By doing this they can observe how the model behaves and check the correctness of their selection. Exploration of a model is in addition offered by the tools provided for the creation of graphs, value tables. The students can furthermore reflect the procedure of creation of the modeling by studying the history of their actions.

A key question to investigate is how the concepts are represented in the modeling space. Abstract representations may be used to represent the state of a variable, like a bar or an arc, see for example fig.3.

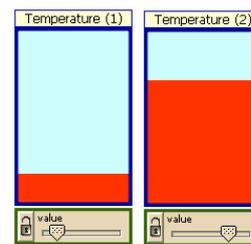


Figure 3: Representation of Temperature

One alternative is to use realistic images like the barrel in fig.1. An alternative possibility is to let the teachers, or even students in some cases, use video of the behavior of real objects of their physical environment. An example is the instruments of the physics experiment which participate in the activity. In this case a direct mental mapping may be made between the experience in the physical world and the modeling activity, see fig.4.

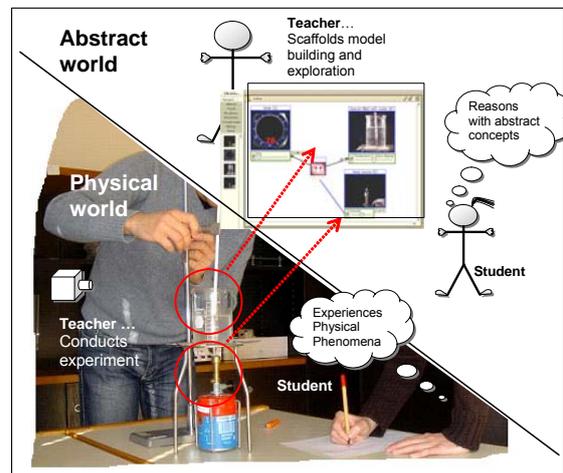


Figure 4: Mapping between physical and abstract worlds in the case of a physics lab experiment

Our research attempts to study if the representation of the concepts through real life objects, familiar to the students, increases the educational value of the activity and the modeling process. In particular in this paper

the feasibility of use of tools for creating abstract entities from video - recorded phenomena by teachers of Primary and Secondary education is being studied. In order to conduct this research we first built a new tool (the *Video2Frame* utility), that was integrated in the *ModellingSpace* environment, permitting easy transfer of low resolution video, captured usually through portable devices like mobile phones, into modeling entities.

The process of design of new educational material, using this approach and tool has been studied and an example is discussed here. This process involves conception of the educational activity, creation of the necessary multimedia material and conversion of this material into appropriate representations supported by *ModellingSpace*.

In the rest of the paper, first we discuss the proposed modeling process and various representations involved. Then, we present the *Video2Frames* tool of *ModellingSpace* which was used in order to create the educational material by allowing the creation of new entities from video - recorded phenomena. Afterwards we present and discuss a case study concerning the transition between real-world objects to more abstract representations, entities created by teachers of primary and secondary education.

2. Modeling Process and Tools used

ModellingSpace [4],[5] has been used in the case study presented in this paper. This is an open learning environment which supports synchronous and asynchronous collaboration for problem solving through modeling. A model in this environment is made of entities connected by relations (Figure 5).

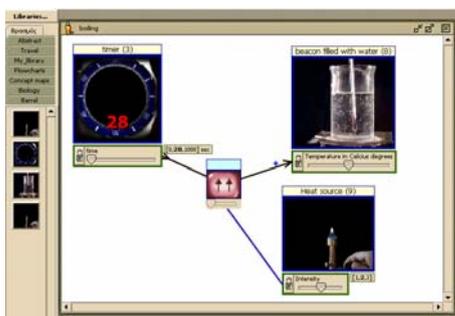


Figure 5: A ModellingSpace model

There are different types of entities: Entities which are static, cannot be quantified, do not have properties and only have one state, represented usually through text or a static image. There are also entities which can be quantified, representing variables. These entities

have properties which can have a value and different states which can be modified. The users can insert these entities in the workspace and use different types of relationships to create qualitative, quantitative and semi-quantitative models.

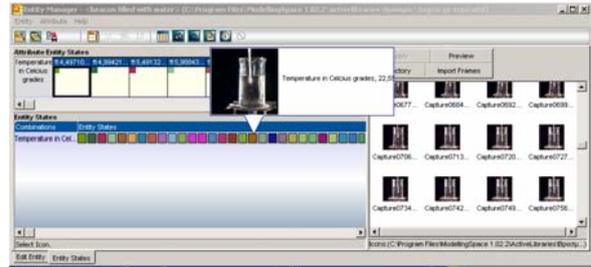


Figure 6: Creation of a new entity

Educational content can also be added by the teachers in order to create activities customized to particular educational needs. Easy to use tools are provided for the creation and import of educational scenarios and entities. The availability of an *Entity editor* that allows fast and easy entity creation suited to the needs of the teacher, as shown in Figure 6, facilitates the teacher to focus better on the planning of the educational activity. The entity creation involves definition of the representation to be associated to various values of the properties of the new entity. In the previous version of *ModellingSpace* the only possibility was to associate still images to different values. This is quite cumbersome and time consuming activity.

There was therefore a need for a tool that would allow creation of entities that represent the physical world into the learning environment in an easy and not very demanding way in terms of resources. The teacher should be able to use a portable device like a mobile phone (provided it has a camera) or a photo-camera to make videos of objects of the real world and easily import them in a modeling environment. In order to meet this requirement the utility *Video2Frames* was built and recently integrated in the new version 1.04 of *ModellingSpace*. This tool is briefly described next.

Video2Frames tool is a new utility specially designed to help the users of *ModellingSpace* (teachers, students etc) to create new entities from videos captured by portable monitoring probes and mobile devices. This utility is incorporated in the *Entity Manager* environment and is mainly addressed to teachers who wish to design educational material and activities using *ModellingSpace*. Its aim is to help them produce sequences of snapshots from video files and insert them to new entities. Apart from the

common video formats (.wmv, .avi, .mpeg), Video2Frames supports the new formats that are used in portable devices such as .mp4 and .3gp.

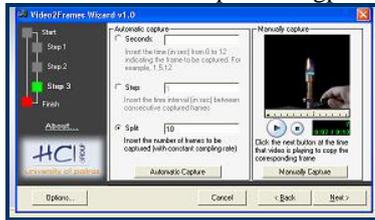


Figure 7: Entity Editor and Video2Frames screenshots

The Video2Frames utility bears the form of a wizard that is integrated seamlessly in the Entity Manager, see fig.7. The process of importing video in a new entity consists of four main steps. Following these steps, the user can determine the input video file, the destination of the captured frames and the desirable number of the frames to be captured and mapped to values of the entities, creating the desire behavior for the new entities.

3. A Case study

A case study took place in order to study the process of creation of new entities from video - recorded phenomena through the use of the tools discussed in section 2. Six educators took part in the case study: two science teachers of Secondary Education and four teachers of Primary education. All the participants found the use of the Entity editor and Video2Frames easy and referred to the positive contribution that these tools can have in the process of designing modeling activities and the educational value of entities created by video-recorded phenomena. The subjects of the first case study were experienced users of ModellingSpace and had previously designed a series of educational activities. The subjects of the second study were unfamiliar with the learning environment and did not have any experience in designing and creating educational material for the specific environment. For this reason a short introduction to the tools was made at the beginning of the second case study.

At this point we will present in detail the procedure that the educators followed in order to create the modeling activity.

In the first case study the teacher consulted the National Curriculum of Greece for Secondary Education in order to determine the educational goals of the scenario. In specific, the educational goals and tasks were aligned with respect to the Second Grade's

Junior High School curriculum for Physics. This educational curriculum specifies that students in the second grade of Junior High School should be able to understand basic phenomena related to heat. The goal is to create a model representing the different aspects of water heating and boiling.

The educational tasks included conducting of an experiment in a physics laboratory with instruments appropriate for this objective and creation of a model in the ModellingSpace environment. The concepts involved in the scenario were the *temperature*, *heat* and *heat transfer*. A worksheet was created to guide the students through the activity. After the creation of the worksheet the selection of entities to be used took place. The educator decided to create two new entities: a “*Beaker with water*” and a “*Heat source*” to represent the key concepts of the activity. She also set the properties of the entities and created two videos by using a low resolution camera for capturing the different states of the properties of the entities. The instruments needed for conducting the experiment were found in the physics laboratory: a heat source (to boil the water), a glass thermometer (Celsius), distilled water, a berzelius beaker, a ring stand, a clamp to hold the thermometer and a timer. The same material is also used by the students during the activity.

The teacher recorded the water as it heated up inside the beaker. She also created a second video of the heat source in different levels and used *Video2Frames* to import these two videos to the *EntityEditor*. She first created an entity which was named “beaker with water” and gave it one property named “temperature” (which in our case is the property of interest). She inserted 200 different entity states and she imported frames from the video she had recorded in the laboratory. She also created a second entity with the name “heat source”. She set the property “levels” and inserted frames from the video for the different states of the entity.

The complete description of the activity is presented in the worksheet which was created. The worksheet includes firstly the goal of the activity and relative questions in order to introduce the students to the problem. Typical questions posed are: “*What do you think will happen if we put two beakers filled with the same amount of water over two heat sources with different levels of heat? Will it take the same time for both of them to boil? Will they boil when they reach the same temperature?*”.

Materials necessary for the experiment (as described earlier) and instructions for conducting the experiment followed the safety instructions. The students are asked to fill the beaker about half full with distilled water and place it on the heat source and heat

until the distilled water boils. They also have to measure the temperature of the water every 30 seconds by using the thermometer and the timer and fill a table. Next they have to repeat the experiment by using the same heat source but after reducing in half the level of heat provided by the source. Then, they have to complete a second table and create a graph representing the values of the two experiments.

After completing these tasks they are given questions, like: “Are you now able to answer the questions we posed in the beginning? Do you think there is a relation between the temperature, the time it takes the water to boil and the level of heat provided? If yes, what kind of relation do you think there is?”.

After completing their work the students are introduced to the Modelling Space environment where they have to create a model with their ideas about water heating by using the two new entities based on the videos of the experiment and an entity of a timer already provided by the environment. They have to insert these entities and connect them with the relations they think that exist between the abstract ideas represented by the entities. They also have to create graphs, charts and value tables in order to reflect on the model they have created.

The defined scenario was tested with a 13 year-old student of the Second Grade of Junior High. Our goal was to certify that the new entities created by the *Video2Frames* utility can be used successfully by typical target users. The student was introduced to the scenario and the environment. He conducted the experiment, collected data and filled out the worksheet. He used the provided entities, and created a model of the phenomenon of boiling and heat transfer. He also created graphs, charts and value tables, according to the activity sheet. The student managed to build the desired model under the supervision of the teacher. He stated correct arguments when answering the questions posed in the worksheet and he also inserted correct relationships between the entities in the model.

Finally in a complementary study two teachers created educational material for a science course and in particular the *Study of acceleration of objects during free fall*. They created videos of an object in free fall by using a camera. Then they built relevant entities. The entity created represented the free fall of an object and had one property, the “height”. In this case, like in the previous one, the teachers, found the facility of building new entities, using captured video intuitive to use and managed to build the entities in a short time.

4. Conclusions

Learners can benefit in many ways by their involvement in modeling activities. However selection of appropriate representations in modeling may influence the learning process. ModellingSpace enhanced with Video2Frames wizard supports easy integration of real life representations in entities that support modeling and scientific reasoning.

The interviews with the educators revealed that the Video2Frames tool of the Modelling Space environment provides a powerful way to prepare educational modeling activities in a significantly less time than previously, provided that the users are familiar with key concepts of modeling.

The ability to create new entities in such an easy way gives an increased affordance to the teachers to prepare educational activities involving modeling representations, permitting linking of students experiences with abstract modeling variables.

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