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TECHNOLOGY BASED MODELLING ACTIVITIES AND THE CONTRIBUTION TO LEARNING CONCEPTS' RELATIONS IN PHYSICS

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During the last decade there has been an increased interest in technology based modelling environments for learning purposes. Current related research has focused mostly on modeling abilities, while there has not enough studies on the eventual effects on learning the underlying concepts. This work presents and discusses the results of research that was carried out with a sample of Greek students aged between 14-15, using the modeling environment "MODELLINGSPACE". The students worked in teams and performed worksheet-based-activities related to physics (kinematics). The research data analysis shows the contribution of technology-based modeling activities to the students' ability to link concepts with representations and achieve an in-depth understanding of their place in the relevant conceptual network. The present paper presents, as an example, observations related to the relation of proportion, and the distinction of dependent –independent variables.

1 Introduction

The use of computers in teaching physics began in the early '70s. Over the last ten years there has been an increased interest in modelling activities and a significant number of modelling tools have been developed that addressed young students. Empirical research on modelling in physics education started in the late '80s.

Most of the actual research related to the modelling environments for learning purposes, focuses on modeling process, or on scientific laws discovering or validating [5]; [6];[7]; [11]; [12];[13]; aspects that are significant. However, there is a lack of research that shows the possible modeling activities contribution on scientific concepts' understanding, as well as on the effects of the representation of modeling primitives (that each system support) to the students' conceptualization [3], [14].

In sciences, 'concepts' function as structural elements of the cognitive edifice. In the scientific theory, a concept relates to others via axioms, definitions and/or laws, the network of which, constitutes the organisation of the concept. In the mind of the students, the concepts are feebly structured and partial. However, a concept conceived in isolation is practically without meaning and useless. Most students think of Physics as a collection of facts that have to be memorized. This tendency weakens their ability to discern the beautiful structure of the natural world that science reveals to us [4].

In traditional teaching a lot of significant concepts are introduced with a sequence that does not provide the students with all the necessary information required to comprehend. We consider that understanding concepts and the relations among them is greatly facilitated by the use of modelling tools [15], taking into account that the modelling process forces students to change their vague, imprecise ideas into explicit causal relationships [9].

The aim of this communication is to present some of the results of our investigation into modelling activities related to kinematical concepts. For this purpose, we have used MODELLINGSPACE [2]; [8], an environment that was especially designed to allow students from eleven to seventeen years old to express their ideas and gradually develop them. In section two of this paper, we briefly present the modelling environment as well as the research questions. Then in section three, we report the results of the research concerning the contribution of the modeling activities to the development of the ability to distinguish the independent from the dependent variable and to understand the relation of proportion. Finally, the last section summarizes and discusses the conclusions.

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2 Research questions and modelling environment description

The aim of the research we conducted was to study how the modeling activities help students attain a scientific understanding of alternative concepts and of the relationships among them. The research was carried out with a sample of 12 Greek students aged between 14-15. The students worked in teams and performed worksheet-based-activities, during 6 sessions. The subjects of the activities were specifically designed to be comprehensible to students from 15 to 16 years old [2]; [15].

The worksheets are designed in such a way so as to enable the students to elaborate on the proportions at issue via situations of modelling. The tasks assigned to the students require them to reason first qualitatively, then proceed semi-quantitatively and finally develop a fully quantitative reasoning.

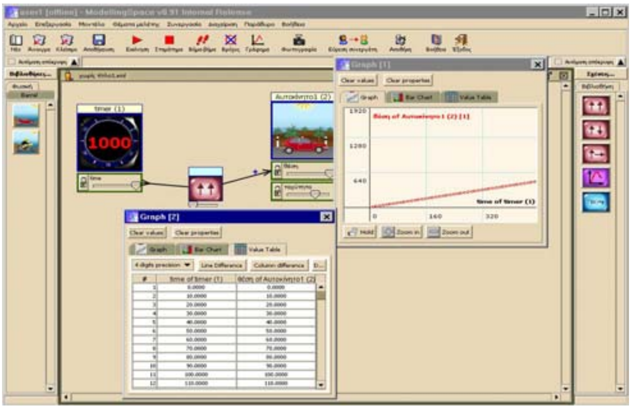

Figure 1 Snapshot of MODELLINGSPACE

The MODELLINGSPACE enables students to build their own models and offers the choice of observing directly simulations of real objects and/or all the other alternative forms of representations (tables of values, graphic representations and bar-charts). The students -in order to answer the questions- formulate hypotheses, they create models, they compare their hypotheses with the representations of their models and they modify or create other models when their hypotheses did not agree with the representations. It is to be noted that one of the specificities of MODELLINGSPACE rises on the fact that incorporates multiple modelling modes and a wide range of entities and variables (from the most concrete to the most abstract ones). Moreover, it supports various representational forms, and allows the expression through the greatest visualisation, combining the modelling tools with real world simulations (not only abstract ones) [2].

3 Research results

The concept of 'proportion' has a prominent role in teaching Mathematics and Physics. Despite its prominence and its constant use in all levels in education, researches concerning math-teaching methods [1] have proven that this concept is difficult to grasp and render manifest that it can be fully understood only within a framework of problems-solving activities. The relations of proportion play a central role, into the variables of kinematics. It is to be noted that the Greek students are introduced in Kinematics through the study of rectilinear motions. In our research we studied how especially designed modeling activities contribute to the deeper understanding of kinematical concepts and the relations among their magnitudes. The research presented is qualitative one and it is based on data that include the students' answers on worksheets, the video on PC's screen, the student's-students dialogs and the interviews. The results presented here are based on the microgenetic analysis of students' dialogs and actions.

3.1 Independent-Dependent Variables

In order to become able to interpret scientifically phenomena of everyday life, students initially need to distinguish the cause from its effect as well as the independent from the dependent variables. In

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MODELLINGSPACE, the user has to distinguish the independent variable that is discerned by the type of lines. In model of Figure 1, the 'time' is the independent variable. The students' worksheets have been designed in such a way so as the students to think about the type of the variables and the relation connecting them in order to proceed-for a start-to a rough scientific organization of the concepts at issue.

Analysing the corresponding research data, we noticed that the students can not distinguish the independent from the dependent variables, especially during the initial activities. By quoting some of the students' dialogues in chronological order, we can notice the positive contribution made by the modeling activities to the deeper understanding of the dependence of the first magnitude's values on those of the second one. In the first activity the student "Giorgos" made the following question. *"Let say that time is proportional to position. Is this the same as saying that position is proportional to time?"* Next week "Giorgos" worked with another student "Tasos" who was not present in the previous activity. They were both asked to fill in some missing values in a table constructed to relate position to time and then to explain how they reasoned in order to accomplish their task. "Tasos" justified their choice saying that they opted for the specific values *"because time is proportional to position"*. After this answer, we had the following dialogue:

S232 Giorgos: *Because position is proportional to time.*
S233 Tasos: *Oh! Yes. Because time is proportional to position.*
S234 Giorgos: *Because position is proportional to time.*
S235Tasos: *Why?*
S236 Giorgos: *Because position is proportional to time.*
S237 Tasos: ...
S238 Giorgos: *What are you saying; No one can affect time.*

It seems that "Giorgos" had understood the concept of the magnitude-dependence qualitatively and in depth. He did not recollect his answer and he used sound arguments with a view to convincing his colleague. Another characteristic example is what another student "Anne" said: *"Position is proportional to time…or time is proportional to position? Oops, what am I saying?"* Next, we noticed that her team linked the variables correctly.

3.2 Relation of proportion

We asked the students to answer questions concerning the change in the constant of the relationship of proportion like *"what can you change in the model so that the motorcyclist increases his speed?"* It is to be noted that the user of the MODELLINGSPACE can change the values of the constant. We found that, even though the students had been previously taught (during traditional lesson) what the constant of proportion is, they were still ignorant of the concept's exact meaning.

The types of confusion we noticed in a number of activities are as follows:

i. Some students answered correctly
ii. Some of them considered the proportional relation as a constant relation.
iii. Some others, when -following the worksheets- they changed the value of the constant of proportion, incorrectly, concluded that the relation between the two magnitudes was not proportional any more.

When the value of the constant of proportion relation was one, we noticed that the students used to grasp

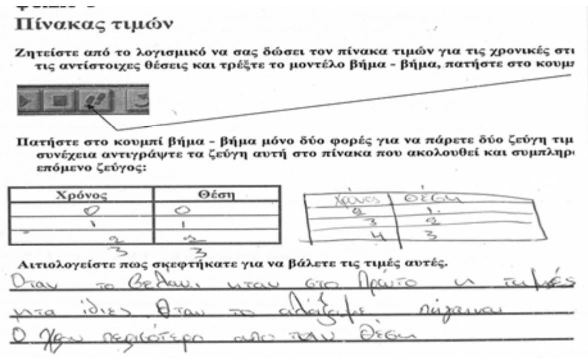

Figure 2 Right-hand table is inconsistent with proportional relation. '*Χρόνος*' = Time, '*Θέση*' =Position

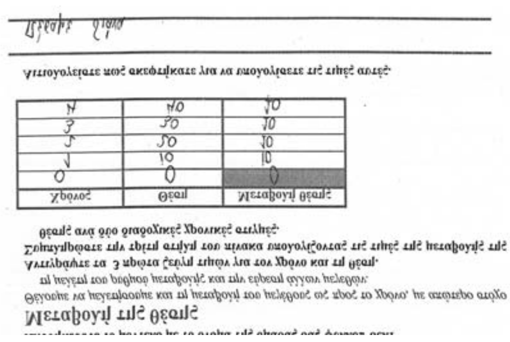

Figure 3 Proportional relation instead of constant relation. '*Χρόνος*' = Time, 'Θέση' =Position

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the relation of proportion as well as its representations. In all the cases, the first indication of some confusion appeared when the constant of proportion was different from one.

The students trying to show how the value of the position changes in relation to the time filled in the left-hand table, presented in Figure 2. With their own initiative they constructed the right-hand table to bring out another case in which the constant of proportion takes a different value. We can notice that the right-hand table is inconsistent with proportional relation. One group, commenting on the change of the position-values in relation to the time-values as presented in the table in Figure 3, responded as follows: *"…it changes in proportion to the time*". Similar was the answer of another group. Some of the right answers could be that change of the position is constant or that is always ten.

During another activity, the students constructed a correct model in which the position was proportional to the time. However, when they were asked to construct another model for the same motion, in which the velocity (and not the position as in the previous one) was related to the time, one group confused the relation of proportion with the relation of constant. Another indication of underlying conceptual difficulty is the answer given on a worksheet of another group. When they were asked to change the value of the constant of proportion they answered as follows: *"If we decrease the constant the time is not proportional to the position"*. The same group when asked 'what one can conclude if one increases the constant of proportion?' responded that "*in this case both the time and the position increase*". Concerning their reasoning during modelling, we found that they used to check whether or not the relation they choose in their model was correct by comparing the graph they had predicted with that provided by their model. They found out that the relation they used was inadequate because the model's graph was not in accordance with their prediction. Most students then discovered that the constant of proportion is represented by the slope of the graph.

In most advanced activities, where the students worked with quantitative reasoning we observed that they were expressing their ideas more adequately. Trying, for example, to express the change of one magnitude in relation to the other (time), they put it as follows: *"The displacement is constant concerning the time in equal time intervals"*. This formulation shows that they grasped deeply the significance of the relation and were able to distinguish the independent from the dependent magnitude. We have also observed (from video data) that other students were impressed by the results effected by the changes in the factors of quantitative expressions, in the simulation of the running model and they often found themselves in a state of cognitive conflict.

We concluded that the possibility given by the ModellingSpace environment to change the constant of a relation, the simultaneous observation of the simulation and the construction of graphs and/or of table of values, contribute to the understanding of the relation of proportion and the interpretation of its graph. We quote some of the students' dialogues in which they justify how they made the motorcyclist run faster by increasing the constant of proportion.

S 521 Heleni: *The more the value of position increases the more the value of velocity increases too.*

S 522 Anna: *Yes, because 20 divided by 1 equals 20, it is not 10. (*10 was the velocity value in the previous case when the value of the constant of proportion was less*.)*

'Heleni' grasped the relation of the position to the velocity and came to realize that increasing the velocity affects the relation of the position to time. 'Anna' calculated the value of the velocity (20) from the new values in the table provided by MODELLINGSPACE and compared it with the previous one (10).

4 Conclusions

During the traditional lessons, students are solving problems, which usually require the use of algebraic relations. Problems of this kind were also solved by students who participated in the present research. We noticed that certain self-evident topics like the simple relations of proportion, which –likely- is the easiest to grasp, have not been comprehended by the students. It is not uncommon to find students who are able to solve problems by using complicated relations without getting a qualitative and in-depth grip on them. Researchers have already shown that students often have a formal mathematical and physical knowledge without a qualitative understanding of basic concepts and relations" [6]; [9];[11].

Concepts not yet understood by the students, and inappropriate mental representations are especially difficult to trace and students cannot manifest them, unless they are invited to deal with situations that require high order thinking. Situations of this kind appear more often in modelling activities than in traditional education. The modelling activities that utilize the full potential of an appropriate technology based learning environment with multiple representations contribute positively towards construction of the scientific concepts and discovering of their relations among them, while support the students who previously had only a feeble grip on them, achieve an in-depth understanding.

The student deal with complex situations, do not have to do routine work, like numerical calculations, or to manufacture many graphs. These assignments get them tired, distract them with trivia and deter high order thinking. With the aid of modelling activities the students are able to approach more complex situations, to really think in terms of scientific variables, to understand the transformations of the situation under study into relational terms [11], to choose the most appropriate representation/s on screen, and thus to solve more complex problems. Technology based modeling environments could be used during guided discovery activities (guided by well educated teachers), for conceptual construction and change, even before working on complex modeling processes.

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