Analysis of Science Students' Views About Models And Modelling

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Abstract

The aim of this study was to gain an insight into the understanding of the (31) physics, (87) mathematics (34) biology and (62) science students, studying at faculty of education, about models which play an important role both in science and science education. For this purpose, a questionaire was developed from Treagust's (2002) research to find out the students' views about what a model is, the role of models in science, how and why models are used and what causes models to change. The students were asked to fill in the questionaire with 31 items; one of them was open item and the others were Likert-type scale. The items of Likert-type were categoriezed under five groups, each one having explicit charactristics, process, examples, uses and changes of models. The student answers were evaluated under the sections "models as multiple representations" (MR); "models as exact replicas" (ER); "models as explanatory tools" (ET); "uses of scientific models" (USM); "the changing nature of models" (CNM) and "examples of models" (ME).

Introduction

The terminological meaning of model and modelling in science is not so narrow in scope as the dictionary meanings of these words. While in science literature modelling is described as all of the processes to make an unknown target clear and understandable depending on the present resources. The product obtained from modelling is regarded as a model. These definitions suggest that in science the limits of modelling and models cannot be clearly determined as is done with word meanings in dictionaries. In fact, the terminological meanings of modelling and model simply summarize the steps the scientists follow to discover new products (law, theory, principle, equations, formula etc.) and the results of these steps within the scope of scientific procedures. The fact that Adams and Le Verier predicted the existence of Uranus which is the eight planet away from the Sun by using a model dependent on the gravity concept and soon after this prediction some further observations confirmed the existence of Uranus or that the atom model proposed for the first time by Thomson was replaced by the atom models of first Rutherford and then Bohr in the light of the recent findings. These two examples may help to understand the use of models, the role and scope of modelling in the discovery of new scientific products. The examples given so far also provides an explanation to the questions why science students should use and develop models in the science classrooms (Harrison, 2001; Van Driel and Verloop, 1999; Harrison and Treagust, 2000).

Modelling and models are indispensable components of the teaching of science. Especially, the abstract nature of science broadens the functions of models and their uses in classrooms. It may be quite difficult to make some concrete concepts accessible and understandable for the students as well as the abstract concepts. For example, electric field lines as abstract concepts or the atom and its structure as concrete concepts are not the concepts students may directly interact with. Such difficulties urge one to produce new solutions to be able to teach these concepts to the science students. That is to say, when one considers that the electric and magnetic field strengths are represented as groups of lines in physics or chemical bonds are represented as sticks and atoms as small balls to explain atom structures in chemistry, the importance of modelling and models becomes clear in the teaching and learning of science (Harrison and Treagust, 2000).

The Groupings of Modelling and Models

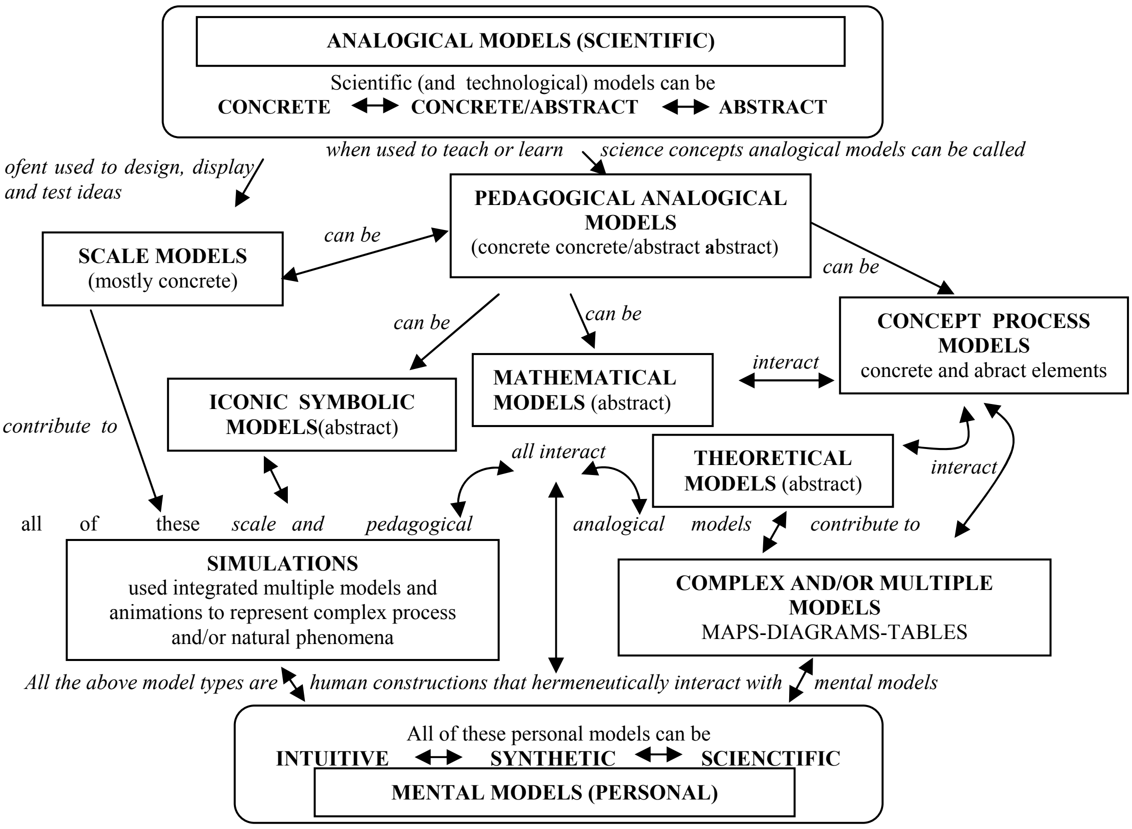
It is quite difficult to determine the limits of the scope of a model. Several researchers report that the identification of the characteristics common to all scientific models is more explicative than the general definition of a model. Van Driel and Verloop (1999) described the common characteristics of scientific models as follows;

- A model is always related to the targets it represents. The target may be a system, an object, a fact or a process.

- A model is a means of research used to obtain some information about a target that cannot be observed or measured directly.
- A model does not interact directly with the target it represents. For this reason, a photograph or spectrum connot be regarded as a model.
- A model is dependent on the analogies suitable to the target and thus enables one to create testable hypotheses about the target. A model always differs from the target in remarkable details.
- The similarities and differences between a model and a target should provide the researchers with the possibility of predictions about the target in the process of creating a model.
- A model is developed as a result of some processes affecting each other mutually and it may be revised in the light of some new studies about the target.

Grouping the models enables us to emphasize the differences between the models. Up to now there have been various groupings depending on some studies; such as scientific and nonscientific models, models according to appearances (abstract or concrete), models according to their functions (identifying-explicative-descriptive). The following is a schematic example of a detailed grouping prepared by Harrison and Treagust (2000).

Fig. 1. A concept map of the typology of concept-building analogical models (Harrison & Treagust, 2000)



Modelling

While the concept of model refers to the product obtained through some processes, modelling refers to the operations used during the procedure. The two main elements of modelling procedure are the source and target. The source includes all of the knowledge and experiences obtained so far. The target is the information that will be obtained by the help of the sources; in other words, it is the knowledge aimed to reach at. With the help of the sources some predictions can be made about the target and their truth could be tested. If the results obtained could explain the target as aimed, the model presented is acceptable. Otherwise, the present information is evaluated again. However, it shoul never be forgotten that any of the models cannot represent any targets fully. If they did, the model would be the target and there would be no need for a model. Still, the model or models used in certain times to explain a fact may be abondoned or changed in the light of new findings. This suggests the idea that models are not permanent facts (Justi and Gilbert, 2002).

Purpose of Research

It is not wrong to define modelling in general as a scientific thinking and studying. Models are the products of modelling process. It is clear that both the use of models and the modelling process have a central role in the teaching of science. Since the main goal of science teaching is to enable students to develop scientific thinking and skills, students should be helped to understand the nature of models and modelling in the classroom and to make them practice these as individual or group work. The following is the summary made by Justi and Gilbert (2002) about the features of models the students are required to know.

- to learn science: Students should know the nature, function and limitations of main scientific models.
- to learn about science: Students should be able to understand and evaluate the role of the models in the scientific products confirmed, shared and spread by scientific researches.
- to learn how to do science: students should be able to create, express and test their own models.

For this reason, our study deals with the ideas of science students about models and modelling. Our aim is to reveal student views about the roles of models in the teaching of science

Method

The Sample

This study was carried out with the participation of 214 first year students at the Educational Faculty of Gazi, 31 students from physics department, 87 students from Mathenmatics department, 34 students from biology department and 62 students from science department. The students had not taken any courses before about models and modelling. They did the test depending only on their previous experiences.

The questionaire

The first 26 Items of 30 Itemed-testing were taken from Treagust's study (2002). The last four items were added to find out the science students' ideas about scientific model examples. Thus, a Likert-type test of 30 items with five choices for each item was prepared. There were choices labeled as (SD) strongly disagree, (D) disagree, (NS) not sure, (A) agree and (SA) strongly agree and science students were required to choose the most suitable ones for themselves. At the end of the test there were open-ended questions and some space was provided for the students to write about the examples of the models they had in their mind. The Cronbach alfa (α) reliability factor was calculated as 0,76.

Groups of Items

30 items in the test were grouped so as to determine the students' ideas about what the models are, what roles they have in science, how and why they are used, what caused them to be abandoned or changed and what is a model (Treagust, 2002). This grouping is shown below:

The items in MR group were prepared to reveal whether students agree that models are multiple representations or not. One of the examples is as follows; Many models may be used to express characteristicss of a science phenomenon by showing different perspectives to view an object (Item-1).

The items in ER Group indicate the perceptions about how much a model can resemble the target it represents. Item-8 that a model should be an exact replica is one of the examples.

The items in ET group are related to the contribution of the model to the students' understanding of any phenomenon. This group covers creating mental models or concrete representations. One of the examples is as follows; Models help to create a picture of the scientific happening in your mind (Item-17).

Table 1. Grouping items for objectives

Items	*Groups of Items*
1-7	*MR: Models as multiple representations*
8-15	*ER: Models as exact replicas*
16-20	*ET: Models as explanatory tools*
21-23	*USM: Uses of scientific models*
24-26	*CNM: Changing nature of models*
27-30	*ME: Model examples*

The items in USM group aim to determine the students' ideas about how models can function besides their roles as descriptive or explanatory. The Item-23 that Models are used to make and test predictions about a scientific event is an example.

The items in CNM group are related to their continuity. One of the examples is the Item-24 that A model can change if new theories or evidence prove otherwise

Finally, the items in ME group are used to determine whether students are aware of the models used in science. The Item-28 that tables, formulas, chemical symbols and schemes are models is one of those examples.

This test aims to find out the limits of the students' ideas about models. The fact that there were more items than only one item with the same aim in the testing groups shows whether their ideas are consistent or not. Item-4 can be put both in MR and ET groups. Similarly, Item-13 and 14 are covered both in ME and ET groups. That some testing items complement each other makes it easy to determine student ideas

Discussion

a) Models as multiple representations (Table-2, Items 1-7)

The alternate models designed for any phenomena provide different points of view and physical images for the happening aimed to be explained. A great number of students agreed on this idea (Items 1-7). The scores in the table indicate that students agree on the idea that a lot of models can be used to express the characteristics of a scientific happening. Besides, students disagree on the idea that a model includes everyting necesssary to show or explain a scientific happening (64,1%) and it reveals that students are aware of the fact that there might be some common characteristics between models and the things they represent as well as some other characteristic not shared by them (Item-7). Their awarenes results from the idea that any of the models never represent any facts fully and if they did so, the model woul be the fact itself.

b) Models as exact replicas (Table-2, Items 8-15)

While 66,3% of the students disagree on the idea that models are exact replicas, 23,4% of them agree on and 10,3% of them were unsure of the idea (Item-8). The percentage of the students who agree on the idea that a model should resemble a real object is 21,9 (Item-9). When one considers the representation of electric field lines, it is very clear that a model does not need to resemble the target it represents. A similar situation is of question for Item-14. 19,2% of the students think that models can represent what the real object is and what it looks like. But, the responses given to items-10, 12, 15 contradict with the responses given to the other items in ER group. It is interesting that 41,1% of the students think models should bear an indisputable resemblance to the real object they represent. The percentage of the students who believe a model should resemble the real object in every ways except from the size is 46,3. 41,5% of the students express models as the reduced forms of objects. Generally, the responses given to the items in ER group indicate that students agree that models should be nearly similar to the fact they represent.

c) Models as explanatory tools (Table-2, Items 16-20)

Students are aware of the role of the models as explanatory tools. The mean values in this group confirm this idea. 87,4% of the students express that models can represent the facts visually or physically. Most of them agree on the idea that models help us to form a mental picture of a scientific phenomenon (Item-17). This item emphasizes the existence of mental models. That is to say, students know that there are some rearrangements in the mind about the fact the model represents and it enables us to evaluate the represented fact from different points of view. In paralel to the responses given to Item-16, 75,3% of the students indicate that pictures, diagrams, maps graphs or photographs can be regarded as models.

d) Uses of scientific models (Table-2, Items 21-23)

The percentage of the responses given to the items in this group indicates whether students have enough knowledge about why scientific models are used. 43,9% of the students were unsure about the testing Item-22 that in order to show how models are used in scientific researches, again models are used. The percentage of the students who were unsure about the other two items also attracts the attentions. These percentages show that some students have some confusions about the nature of models.

e) Changing the nature of models (Table-2, Items 24-26)

A great number of the students share the idea that models can change in the light of new findings (Items-24, 25, 26). This situation indicates that students do not regard models as fixed facts but as the ones that can be changed when needed. But it is surprising that 23,4% of the students agree on and 19,2% of them are unsure about the Item-26 that a model can change when there are changes in findings or beliefs. Similarly, the fact that 21% of the students are unsure about the Item-24 indicates that there is insufficient knowledge about the situations models can change in.

f) Model examples (Table-2, Items 27-30)

54,6% of the students agree that models are used to form theories (Item-27) while 26,2% of them are unsure of and 19,2% of them disagree with this idea. While 61,7% of the students regard the tables, formulas, chemical symbols and schemes as models 24,3% of them reject this idea. (Item-28). But, most of the students agree on the Item-29 that maquettes and toys are models. Yet, 42,1% of them disagree with the idea that Newtonian laws, Archemedes principle, Evolution theory and Pisagor theorem are models whereas 34,6% of them were unsure about it (Item-30). The findings obtained from the responses given to the items in ME group show that most of the students do not have enough knowledge about what examples are included in models.

g) The findings obtained from the analysis of the model examples expressed by students

The models science students expressed were analyzed and grouped as seen in the above scheme (Fig. 2). Model examples are limited to scale models, pedagocical analogical models, mathematical models, theoretical models and map-table-diagrams. The findings obtained from this part may give some ideas about the consistency between the responses given to items in ME group (Items-27, 28, 29, 30) and the model examples they expressed. Most of the examples given by the students include scale and theoretical models. Most of the examples about scale models are maquettes. This is consisitent with the percentage of the responses (81,9% of them agree) given to Item-29 (maquettes and toysa re models). However, it is possible that students were affected by Item-29 because firstly the test was presented and then the students were required to give model examples. That the number of the examples about theoretical model is very high is misleading because 42,1% of the students strongly disagree on the Item-30 (Newtonian laws, Archemedes principle, Evolution theory and Pisagor theorem) whereas 34,6% of them were unsure about it. The reason why the number of the examples in the theoretical model group is higher than it is in other groups is that these examples (atom models, particle and wave models of light, DNA model etc.) are already called as models in science literature.

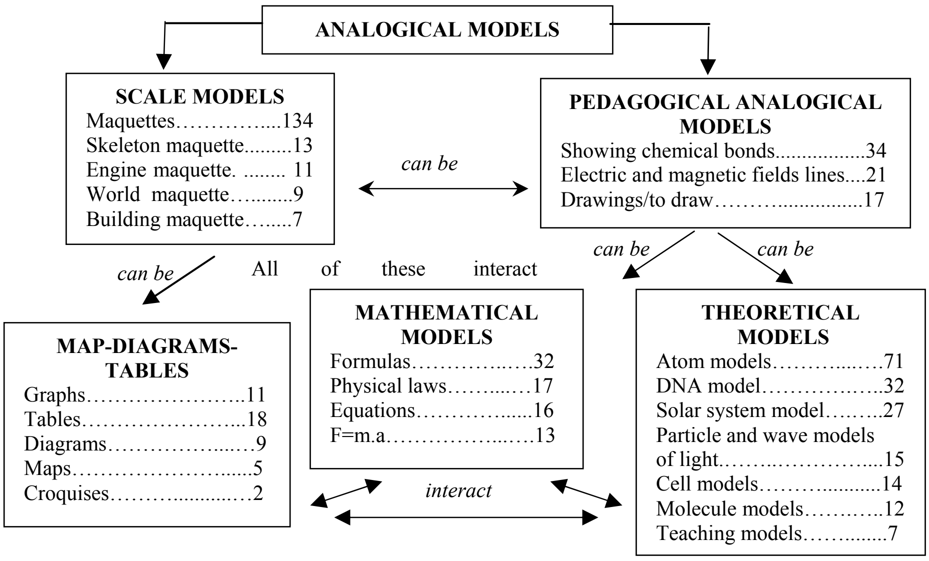
Table 2. Statistical analysis of science students' views about model and modelling

The questionaire items	N	$\bar{x}$	(S)	% D	NS	A
MR1 Many models may be used to express features of a science phenomenon by showing different perspectives to view an object.	214	4,359	0,617	1,9	1,9	96,2
MR2 Many models represent different versions of the phenomenon.	214	3,785	0,978	14	11,7	74,3
MR3 Models can show the relationship of ideas clearly.	214	3,869	,0878	8,8	16,4	74,8
MR4 Many models may be used to show different sides or shapes of an object.	214	4,126	0,832	5,6	3,7	90,7
MR5 Many models show different parts of an object or show the objects differently.	214	3,364	1,129	27,6	15,9	56,5
MR6 Many models show how different information is used.	214	3,743	0,946	13,5	15,9	70,6
MR7 A model has what is needed to show or explain a scientific phenomenon.	214	2,486	1,112	64,1	15	20,9
ER8 A model should be an exact replica.	214	2,331	1,228	66,3	10,3	23,4
ER9 A model needs to be close to the real thing.	214	3,579	1,130	21,9	12,1	66
ER10 A model needs to be close to the real thing by being very exact, so nobody can disprove it.	214	2,850	1,298	47,7	11,2	41,1
ER11 Everything about a model should be able to tell what it represents.	214	4,074	0,813	6,6	8,4	85
ER12 A model needs to be close to the real thing by being very exact in every way except for size.	214	3,130	1,187	38,3	15,4	46,3
ER13 A model needs to be close to the real thing by giving the correct information and showing what the object/ thing looks like.	214	4,028	0,949	9,8	4,2	86
ER14 A model shows what the real thing does and what it looks like.	214	3,593	1,060	19,2	10,3	70,5
ER15 Models show a smaller scale size of something.	214	2,967	1,286	40,7	17,8	41,5
ET16 Models are used to physically or visually represent something.	214	4,121	0,830	7,5	5,1	87,4
ET17 Models help create a picture in your mind of the scientific happening.	214	4,317	0,782	4,7	4,2	91,1
ET18 Models are used to explain scientific phenomena.	214	3,789	0,902	12,6	14	73,4
ET19 Models are used to show an idea.	214	3,602	0,957	15,9	15,9	68,2
ET20 A model can be a diagram or a picture, a map, graph or a photo.	214	3,827	0,975	12,1	12,6	75,3
USM21 Models are used to help formulate ideas and theories about scientific events.	214	3,457	1,023	18,3	25,2	56,5
USM22 Models are used to show how they are used in scientific investigations.	214	3,266	0,821	15,9	43,9	40,2
USM23 Models are used to make and test predictions about a scientific event.	214	3,453	1,050	21,5	18,7	59,8
CNM24 A model can change if new theories or evidence prove otherwise.	214	3,831	0,903	8,4	21	70,6
CNM25 A model can change if there are new findings.	214	3,911	0,870	8,4	13,1	78,5
CNM26 A model can change if there are changes in data or belief.	214	3,373	1,105	23,4	19,2	57,4
ME27. Models are used to develop theories..	214	3,383	1,022	19,2	26,2	54,6
ME28. Tables, formulas, chemical symbols and shcemes are samples of models..	214	3,420	1,130	24,3	14	61,7
ME29. Maquettes and toys are models.	214	3,883	0,964	11,6	6,5	81,9
ME30. Newton Laws, Archimedes Principle, Evolution Theory and Pisagor Theorem are models.	214	2,715	1,112	42,1	34,6	23,3

MR: Models as multiple representations ER: Models as exact replicas ET: Models as explanatory tools USM: Uses of scientific models CNM: Changing nature of models ME: Models examples

$\bar{x}$ *: Mean A:A*agree=*S*strongly agree+*A*agree *NS:N*not sure *D:D*isagree=*S*trongly disagree+Disagree *N:Tthe number of participations to servey S: Standart deviation %:Percentage rate*

Fig. 2. Classified model examples given by science students and the frequency of the examples



It can be concluded that the students who regarded the representations of electric and magnetic field lines and the images of atomic bonds as models (pedagogical analogical models) know more about the nature of models. The same thing can be considered for the students who gave the examples of equations, analogies and F=m.a (mathematical models).

Although the students expressed a lot of model examples included in scale, theoretical, mathematical, map-table-diagram groupings, there were no examples about iconic/symbolic models, simulations, concept process and synthesis models and mental models. While most of the students agreed on the Item-17 that models help us to form mental pictures of the scientific phenomena, it is interesting that no examples of mental models are seen in their expressions.

Conclusion

Our study was designed to determine the views of science students at the educational faculties about what models are, what roles they have in science, how and why they are used, what caused them to cahnege and what are the models. Student views were assessed in paralel to the groupings of testing items.

It is clearly seen that students do not have any confusions about the characteristics of models in MR and ET groups. That is to say, they are aware of the multiple uses of models in science and the use of models as explanatory tools. But it is not the same for the characteristics of models in ER and USM groups because a remarkable number of the students think that models should resemble the real object they represent. Moreover, almost half of them claim that this resemblance should be so great that it could not be changed later. In fact, this makes us think that students have some confusions about the concepts such as models, theories and laws. As a result, they cannot decide what analogies a model should have with the target it represents. Besides, the responses given to the items in USM group lead to the idea that students are not aware of the roles of the models in the discovery of scientific products. The responses given to the items in CNM group indicate that some students regard models as stable facts. The fact that teachers or textbooks writers almost never refer to the models used before and abondoned due to some reasons cause students to perceive the models in this way. Depending on the responses given to the items in ME group, it can be said that students are not aware of the fact that symbolical representations and mathematical formulas are models.

The model examples given by the students are limited to the ones expressed very often. Especially, because most of the students agree on the idea that models should be very similar to the facts they represent, they gave more examples of scale models (earth maquette, building maquette etc.). Similarly the fact that the examples considered as models in science literture are very familiar with the things in their field of study may explain why the number of the examples about theoretical models are so high. The model examples we used in our previous studies carried out with high school students and academicians are almost the same as the ones given in this study.

In conclusion, it is clear that students have some confusion about the nature of modelling and models. This is especially related to the ideas about how much a model can represent the fact and what can be regarded as models. For this reason, students need to know more about the nature of scientific models which are the indispensable part of their learning. Thus, they will have a better understanding of the processes of scientific products and their uses.

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