Teachers' conceptions of scientific models II: Comparison between two groups with different backgrounds

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Abstract

At ESERA 2005 Conference, we presented the results of a Pilot Study on the topic "*Teachers' conception of scientific model"* (Gutierrez & Pintó, 2005). In this paper, we present a continuation of that work. We have used the same questionnaire, now with a group of experienced teachers. As results, we have found some differences, being the most important: 1) it is possible to analyze the data using fewer categories; 2) the highest concentration of answers belongs to the semantic field of "models"; 3) teachers' answers show more coherency than the first group ones. There still remain some unanswered questions. The same questionnaire have been used in Italy, with several groups of prospective physics teachers (see Danusso et al on this Conference). On the whole, we hope to offer some light on the topic.

Introduction. Antecedents and backgrounds of the work here presented

In the last ESERA Conference (Barcelona 2005) we presented a preliminary study on teachers' conceptions of scientific model (Gutierrez and Pinto 2005). How teachers understand models (Justi and Gilbert 2003) and modeling (Crawford and Cullin 2004) is a point of crucial concern in science education literature. The results of the studies related to this issue show a picture far from satisfactory (Van Driel and Overloop 1999). Some of the difficulties pointed out in the literature address the lack of specific teacher training in the issue of models and modeling (Saari and Viiri 2003), and the necessity of studying what a model is from a theoretical perspective (Gilbert and Buolter 1998). This second aspect drew our attention. A review of literature showed that it is not easy to find a clear definition of what a scientific model is (Wells et al 1995, Gutierrez and Pinto 2004): Scientific model is not usually defined, but instead what you find in papers are lists of characteristics. So, we situated our research question: *How teachers understand scientific models,* in the realm of ontology, in order to avoid multiple descriptions not included in the essential part of a definition.

Methodology

From the work of Bunge (1974-1989) we chose a definition of scientific model based on its ontological characteristics. According to him, the essential characteristics of a scientific model (independent of the field to which the model refers) are as follows:

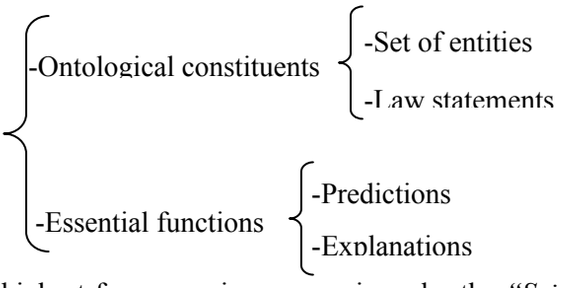
> *A scientific model is a representation of a real or conjectured system, consisting in a set of objects with its outstanding properties listed, and a set of law statements that declare the behaviours of these objects.*

Being the *essential functions* of a scientific model, according to Bunge, *predictions* and *explanations*. With the above elements we constructed a strategic systemic network resulted in Figure 1 (Gutierrez y Pinto 2005:867), which allows us *to develop a questionnaire* with theoretical grounded categories. The questionnaire was validated by a number of experts in different areas, and by a group of teachers with different subject matter backgrounds.

Sample and findings

We tried the validated questionnaire with a group consisting of 21 Spanish teachers (**G1**), with different academic backgrounds. Details of the sample and the results of the qualitative analysis of the answers can be examined in Table 1.

Figure 1



As is shown in Table 1, the highest frequency in answers is under the *"Scientific Theory"* category, followed by (in order of frequencies) *"Scientific Model", "Procedure, "Teaching Method", "Exemplar, and "Scientific Method"*. There were 5 answers *"Impossible to classify"*.
We will say that teachers' answers are *coherent* when the three answers to the questions are classified under the same category. We can identify that this is the case for 9 teachers. This comprises 42,85% of the sample.

The Study with the Second Group

We administered the same questionnaire to teachers of science, to see if there are differences in the results. So, in order to make comparisons possible,
-The *research question* is now: *How teachers* of science *understand scientific models?*
-The *methodology* for carrying out the study was the same as that used with the other group.
-The *sample* consisted of a group of 19 Mexican teachers of science (**G2**) attending a course of Cognitive Science, who voluntarily completed the questionnaire.
If we compare this sample **(G2)** with the sample of the first group **(G1),** two main differences, potentially important for our purposes, can be observed:
-**G1** has much less teaching experience than **G2**.
-In **G2** all the members are graduates in sciences; while in **G1** there was only one science graduate, and few graduated in science-related subjects: 2 Maths; 3 Business (2 diploma); 1 Computing (diploma).

Findings

Details of the sample and the results of the qualitative analysis of the answers to the questionnaire given by **G2** can be examined in Table 2. As with the first group, the categories were inductively established from data.
If we compare **the results** on Tables 1 and 2, interesting details emerge:
1) Categories *"Procedure", "Exemplar", and "Teaching Method"* do not appear in Table 2. On the other hand, a new category appears in this Table, *"Help to explain*", which can be defined as shown in Table 3:

Table 1. Spanish Teachers' sample (G1)

Sample		Classification of teachers' answers to questions 1 (Q1), 2 (Q2), and 3 (Q3)[1]						
Teacher N	Teaching experience	Scientific Theory	Scientific Model	Procedure	Exemplar	Scientific Method	Teaching Method	Impossible to classify
1 Journalism	No exp[6]						Q1c,Q2c,Q3c	
2 Law	No exp	Q1c,					Q3	Q2
3 P.Teacher[3]	No exp				Q1,Q2,Q3			
4 Business	No exp			Q1, Q2c	Q3c			
5 P. Teacher	No exp	Q2c					Q1c	Q3 No clear[2]
6 P. Teacher	2 years				Q3	Q1c,Q2c		
7 Psychology	7 years	Q3c						Q1,Q2 Clear
8 Pedagogy	2 years	Q1c,Q2c,Q3c						
9 Pedagogy	Not stated	Q2c		Q1c,Q3c				
10 Pedagogy	No stated	Q1		Q3		Q2		
11 DD[4] in Business	2 years	Q1c,Q2c,Q3c						
12 Business	2 years		Q2	Q1c				Q3 Clear
13 Translation	7 years	Q3c	Q1,Q2					
14 English	Not stated			Q1c,Q2c,Q3				
15 English	15 years						Q1,Q2,Q3	
16 English	6 years	Q1c,Q2c	Q3c					
17 DD Computing	2 years			Q1,Q3				Q2 Clear No answer
18 Environm[5]	1 years		Q1,Q2,Q3					
19 Philosophy	3 years		Q1,Q2,Q3					
20 Maths	No exp		Q1,Q2,Q3					
21 Maths	3 years	Q1c,Q2c,Q3c						

[1] The "c" character added to "Q" on the table means that the answer to that question is only partly in agreement with the definition of the category. [2]Clear: easy to understand stated in the questionnaire.
[3] P. Teacher= Primary teacher; [4]DD=Degree Diploma (First Cycle University); [5]Environm= Environmental Sciences; [6]No exp=No teaching experience.
-Frequencies: Scientific Theory 17 (10 teachers): Scientific Model 13 (6 teachers); Procedure 11 (6 teachers); Teaching Method: 8 (4 teachers); Exemplar 5 (3 teachers); Teaching Method 3 (2 teachers); Impossible to classify: 5 (4 teachers); No answer: 1.
-Coherent answers: 9 (out 21). 42,85 percentage.

Table 2. Mexican Teachers' sample (G2)

Sample		Classification of teachers' answers to questions 1 (Q1), 2 (Q2), and 3 (Q3)[1]					
Teacher N	Teaching experience	Scientific Theory	Scientific Model	Help to explain	Scientific Method	Others[4]	Impossible to classify
1 C[3]	7 years		Q1,Q2,Q3				
2 B	20 years		Q1c		Q2c	Q3 Technical artefact	
3 B Prim	15 years		Q1,Q3			Q2 No answer	Clear[2]
4 P,C	Not stated		Q1,Q3c				Q2 Clear
5 P,C,B	5 years			Q1c,Q2,Q3c			
6 B	10 years					Q1c,Q2c,Q3c graph.schem	
7 P	15 years	Q1,Q2,Q3					
8 P,C	20 years	Q1		Q3c			Q2 Clear
9 G	3 years			Q1c,Q2c,Q3c			
10 B	22 years		Q1c,Q2c,Q3c				
11 B	1 years		Q1c,Q3c				Q2 Clear
12 P,C,M, 2nd	8 years		Q1,Q2c,Q3c				
13 B	25 years	Q1,Q2c,Q3c					
14 P, Q	22 years			Q1,Q2,Q3			
15 P	30 years		Q1,Q3c				Q2 Clear
16 P,C,B	13 years			Q1c,Q2c,Q3c			
17 P	27 years			Q1c,Q2c,Q3c			
18 C	Not stated	Q1c,Q2,Q3c					
19 B	2 years		Q1c	Q3	Q2c		

[1] The "c" character added to "Q" on the table means that the answer to that question is only partly in agreement with the definition of the category. [2]Clear: easy to understand stated in the questionnaire.
[3] The letters under the number mean that they teach: P=Physic; C=Chemistry; B=Biology; G=Geography; M=Mathematics; 2nd=Secondary (when stated); Prim=Primary (when stated).
[4] Under the heading of "Others" answers given from only one teacher can be found
-Frequencies: Scientific Model 19 (9 teachers); Help to Explain 17 (7 teachers); Scientific Theory 10 (4 teachers); Scientific Method 2 (2 teachers); Impossible to classify 4 (4 teachers); No answer 1.
-Coherent answers: 12 (out of 19). 63,15 percentage.

Table 3. Definition of the new category

Category. Definition	Examples from protocols
HELP TO EXPLAIN: -A representation that is useful for explaining a reality (or activity, or process), or a concept, to others	Examples: -N14, Q1: *"It is a representation of some phenomenon, which serves to scientists for expose its ideas".* -N5, Q2c: *"Representation of the reality studied (phenomenon) to give other people reasons for events, and how we explain the reality to ourselves".*

If analysed more closely, we can observe that
2) In **G1,** most of the teachers with answers categorized under the categories that do not appeared in Table 2 have no teaching experience (5) or little experience (3 two years experience). Only 1 has fifteen years experience. Three teachers did not refer to the issue.
3) In **G2**, the highest frequency is now under the category of *"Scientific Model"*, followed by *"Help to explain"*. The category *"Scientific Theory"* appears only in the third place. If compared with **G1** these changes could be significant.
4) On the whole, answers within **G2** show *more coherency* than **G1**: 63.15 and 42.85 percentage, respectively.
5) In **G2**, the category "Scientific Model" reaches the highest frequency in number of answers and in number of teachers (9; 47.36% of the sample). But the answers are far from precise: Teachers' answers within **G2** convey the semantic field of "models"; but they do not refer accurately to "scientific models" in ontological terms. In **G1**, only 6 teachers gave answers under this category (28.57% of the sample). But, again, the attributed meanings of the answers do not precisely refer to the ontological concept of "scientific model".
In relation to **validity** of the questionnaire, the question Q2 appears four times in **G2** group in the category *"Impossible to classify",* and once as *"no answer"*. This could suggest something about the intelligibility of the question, despite the fact that the five teachers explicitly stated that the question Q2 was **clear** to understand.

Discussion

As was said before, the main differences between **G1** and **G2** samples were: a) teaching experience; and, b) academic background. So, it is necessary to see which of these variables is a better candidate to explain the differences.
We have found some papers that deal with this issue. Thus, Harrison (2001) interviewed 10 experienced science teachers, and he found that physics teachers ranking higher in Grosslight et al levels, followed by biology teachers, being chemistry teachers the lower ranked; Van Driel and Verloop (1999) studied the knowledge of models and modelling in experienced teachers. They reported: *"These results indicate that the chemistry teachers were more strongly committed to logical positivism than the physics teachers, whereas the biology teachers held an intermediate position"*(p 1149). Justi and Gilber (2003) investigating teachers views of the nature of models, report that the educational background of the sample was significant to this respect: *"The FT subsample, four of whom had Primary Teaching Certificates as their major qualification, held the most simple views of the "nature of models".* (…) *Those with a degree in biology showed a very similar pattern"* (p 1380). *"It was only those with a degree in chemistry or physics who were able to discuss the notion of model in a more comprehensive way"* (p 1381).
Apart from the observed differences, all these three papers agree on the existence of relationships between teachers' academic background and their understanding of models.
The paper presented at this Conference by Danusso et al (2006) is especially significant to our purpose, having the same research question as us, using the same questionnaire to gather data about teachers' understanding of ontological concept of scientific model, the only difference being the statistic treatment of the data, due to the greater number of Italian subjects. The sample they work with is similar to **G1** in teaching experience and similar to **G2** in academic background. Examining the overall results, they show that *"Question 2 has been perceived as difficult"*. (…) *"The majority of physicists (56%) and engineers (64%) correctly identify nature, components and functions of scientific models, while this happens only for one third for those having a Math degree*".

For all these we are inclined to conclude that *the better candidate to give account of the differences found between **G1** and **G2** is the different academic background between the two samples.*
In relation to *the validation* of the questionnaire, we remark that from our results question Q2 seems to present some problem for teachers' understanding. The same is exposed by the Italian team: *"Question 2 has been perceived as difficult"*. This means that the wording of this question needs critical analysis in future uses of the questionnaire.

Future implications

For research

From our data, we can say that one influential factor affecting differences in teachers' understanding the ontological aspects of scientific model is their academic background. Nevertheless, more research needs to be done to see the weight of other factors in these differences, e.g. data from the questionnaire could be enriched with interviews, and shed new light on the issue.

For teacher training

Focusing on ontological aspects presents the advantage of concentrating the understanding of the nature of scientific models on fewer and more essential factors, thus lightening the cognitive load of the concept, and facilitating the introduction of its epistemological characteristics. This could represent a benefit for the development of specific teacher training courses based on this theoretical approach.
This paper represents only a first attempt at the study of scientific model and how teachers understand it from a new theoretical perspective. Much research needs to be done to explore the new possibilities offered by this approach.

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References

Bunge, M. (1974-1989) *Treatise on Basic Philosophy*. Volumes: 1-2, Semantics; 3-4, Ontology; 5-7, Epistemology and Methodology (vol 7 with 2 parts); 8, Ethics: the good and the right (Dordrecht: Reidel Publishing).

Crawford, B. and Cullin, M. J. (2004) Supporting prospective teachers' conceptions of modelling in science. *Int. J. of Science Education*, *26,* 1379-1401.

Danusso, L., Testa. I, Sassi, E. and Vicentini, M. (2006) Teachers' ideas about scientific models and modeling. Paper presented at *GIREP 2006 International Conference on "Modeling in Physics and Physics Education"*. Amsterdam, 20-26 August.

Gilbert. J. K. and Boulter, C. J. (1998) Learning Science through models and modelling. In: Fraser, B. J. y Tobin, K. J. (eds), *International Handbook of Science Education*. (Kluwer. London), p 53-66.

Gutierrez, R. and Pinto, R. (2004) Models and Simulations. Construction of a Theoretically Grounded Analytic Instrument. In: E. Mechlová (ed), *Proceedings: Teaching and Learning Physics in New Contexts. Selected Papers*. GIREP 2004 International Conference. (University of Ostrava. Ostrava, Czech Republic), p 157-158.

Gutierrez, R. y Pinto, R. (2005) Teachers' conceptions of scientific model. Results from a preliminary study. In: R. Pinto and D. Couso (eds), *Proceedings of the Fift International ESERA Conference on Contributions of Research to Enhancing Students' Interest in Learning Science*. Barcelona, Spain, pp 866-868.

Harrison, A. G. (2001) How do teachers and textbook writers model scientific ideas for students? *Research in Science Education, 31*, 401-435.

Justi, R. and Gilbert, J. K. (2003) Teachers' views of the nature of models. *Int. J. of Science Education,* 25, 1369-1386.

Saari, H. and Viiri, J. (2003) A research-based teaching sequence for teaching the concept of modelling to seventh-grade students. *Int. J. of Science Education, 25*, 1333-1352.

Van Driel, J. H. and Verloop, N. (1999) Teachers' knowledge of models and modelling in Science. *Int. J. of Science Education, 21,* 1141-1153.

Wells, M., Hestenes, D. and Swackhamer, G. (1995) A modeling method for high school physics instruction. *Am. J. of Physics, 63,* 606-619.