DEVELOPING AND USING EVALUATION RESEARCH TOOLS FOR SCIENCE TEACHING CASES INFORMED BY THE HISTORY AND PHILOSOPHY OF SCIENCE

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Developing Research Tools

For the HIPST Research Project researchers and academics from the fields of History of Science, Philosophy of Science and Science Education joined with science teachers and science museum specialists in order to develop and use science teaching cases informed by the history and philosophy of science. In the developed HIPST cases all the above traditions were incorporated, the cases were applied in primary, secondary and tertiary education audiences and an evaluation research took place. HIPST cases were developed in the context of intergrading history of science, philosophy of science and science teaching in applicable science teaching proposals with a special focus on the teaching of the nature of science and the encouragement of competencies, values and attitudes in the context of scientific literacy.

The GNOSIS Research Model (Seroglou & Aduriz-Bravo 2007) has been used as the theoretical framework for the development of the research tools for the evaluation of the HIPST cases as it combines history of science, philosophy of science, values and attitudes fostered by science (sociology of science), science teaching, nature of science and scientific literacy. GNOSIS is an acronym for 'Guidelines for Nature Of Science Introduction in Scientific literacy' is a synthesis of previous theoretical (Seroglou & Koumaras, 2001; Adúriz-Bravo, 2003). It approaches NOS-informed science teaching through three complementary dimensions:

1. The *cognitive dimension*, dealing both with science as a set of models that give meaning to the world (*nature of science contents*) and with the broader social contexts in which such ideas have come to be (*nature of science contexts*).
2. The *meta-cognitive dimension*, focussing on what science is (*synthetic nature of science as a product*), how science changes in history (*nature of the evolution and methodologies of science*), and how science relates to society and culture (*nature of the interrelations of science and society*, in which the 'cultural print of science' can be appreciated).
3. The *emotional dimension*, which opens the picture to considering attitudes (*nature of attitudes expressed through science*) and values (*nature of values fostered by science*) that are not only fundamental in science as a process, but also desirable in the education of scientifically literate citizens.

Since the cognitive dimension deals with scientific contents and their context of emergence, it can be productively informed by discussions of the history of scientific ideas. Furthermore, the meta-cognitive dimension, tackling the question of 'how do we know what we know?', thoroughly connects with the philosophy of science. And the last dimension, occupied with the contribution of science in the formation of educated people, can be illuminated by ideas from recent sociology of science and science studies (Seroglou & Aduriz-Bravo 2007). In Figure 1, all the above components of the GNOSIS framework are put together.

Constructing a questionnaire for the evaluation of the HIPST cases was a long process including the following steps:

1. Identification of issues that are of interest in this project (nature of science, values and attitudes, self-concept, interest. etc).
2. Detection of previously published measures that tap on the issues identified in step 1 (Liang et al 2006, Makri- Botzari 2001, Jarvis & Pell 2002, Hofer 2000, Brossard et al 2005).
3. Selection of some of the items of these measures and production of more items relevant to our research focus.
4. Construction of an initial version of the questionnaire: The main qualifications of this questionnaire were to be: a) informative (infer as much information as possible) and b) short (so that its administration would not take too long or interfere much with the class work).

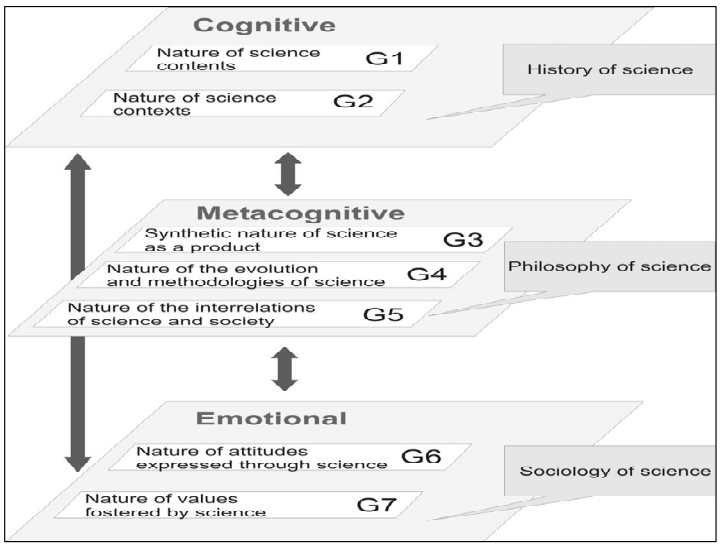


Figure 1: The GNOSIS Research Model

5. Administration of this version to individuals (in "control" and"experimental" groups of different ages).
6. Initial statistical analysis intended to detect items that do notshow any variation and that do not exhibit consistency (test-retestreliability).
7. Discussion with the participants to detect items that they do notunderstand or that they do not understand easily or that they do notunderstand correctly.
8. Second round of discussions amongst the experts to ameliorate thequestionnaire based on the statistical analyses and the discussion with theparticipants.
9. Construction and administration of final version of the questionnaire.

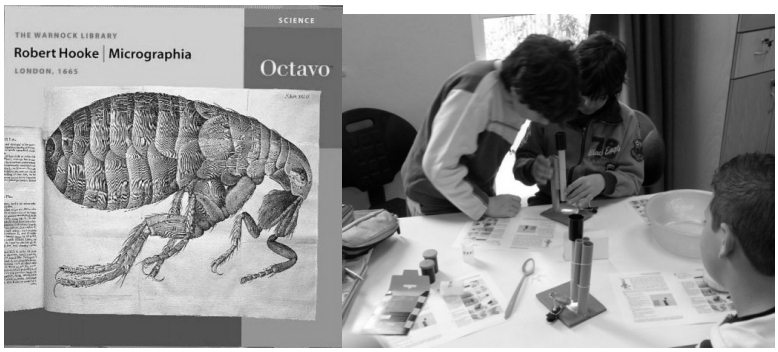
In a pilot study informed us in two ways we traced items that may be difficult to understand and removed or rephrased these items. We also conducted some preliminary statistical analyses in order to find out which items may cause problems in the further use of our measure. The conclusion that we reached, based on the analyses just presented, is that it seems that our measure is promising in terms of capturing individual differences in the variables under investigation. Some items may prove less revealing in some age groups however further research is needed. An important step that still needs to be taken is the test of the test-retest reliability of the measures in different age groups (repeated measurements in a control group).

Implementation of the Research Tools in the HIPST Cases:
Data Analysis and Research Results

The developed questionnaire was distributed to HIPST participating researchers and also uploaded in hipstwiki (http://hipstwiki.eled.auth.gr). HIPST researchers were asked to use the questionnaire before and after the application of the developed HIPST cases to help them in the evaluation of the cases. In this paper, results are presented from the following greek HIPST cases that have been developed by the ATLAS Research Group in the Aristotle University of Thessaloniki and the Science Education Research Group in the University of Patra:

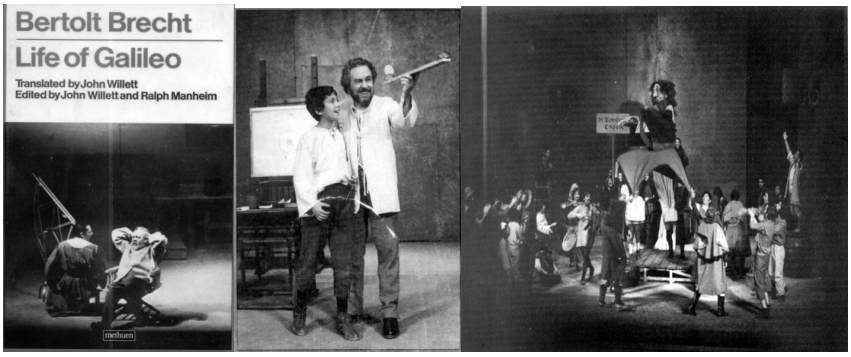
1) From the geocentric to the heliocentric system: Teaching to 11-year-olds in a primary school in Athens about worldviews concerning the place of the earth in the universe from antiquity till the 17th century based on the work of scientists and philosophers using the animation technique - pupils develop their own animation movies (case developed by Panagiotis Piliouras and Spyros Siakas).

2) From Hook's Micrographia to the teaching of the microscope: Teaching about optics and the microscope to 11-year-olds in a primary school in Crete inspired by Hook's Micrographia (case developed by Nektarios Tsagliotis)



3) Teaching about pendulum: A series of courses about the pendulum for in-service science teachers (secondary education) and secondary education pupils (case developed by Sotiris Dosis, Nikos Kanderakis and Dimitris Koliopoulos).

4) Galileo and a place for the Earth in the Universe: In-service teacher post-graduate course at the University of Thessaloniki on the way that the geocentric-heliocentric debate and especially Galileo's work has influenced culture (case developed by Fanny Seroglou)



5) The life and work of Marie Curie: In-service teacher post-graduate course at the University of Thessaloniki about the life and work of Marie Curie, focusing on the teaching of the nature of science and mostly on the nature of attitudes and values fostered by science (case developed by Fanny Seroglou).

6) First women astronomers: In-service teacher post-graduate course at the University of Thessaloniki on women in science till the 18th century. In-service teachers develop and perform a role-play inspired by original writing of men and women scientists of the past (case developed by Fanny Seroglou and Eleni Chatzisavva).

She was a great man whose only fault was being a woman. A woman who translated and explained Newton – **Voltaire**

(for Emilie du Chatelet)

I did nothing for my brother but what a well trained puppy would have done: I was a mere tool which he had the trouble of sharpening – **C. Herschel**

Women are not incapable to study, if they wish to make the effort, because between the brain of a woman and that of a man there is no difference – **J.Dumee**

Even before her husbands' death, the Academy was ridiculed because its calendar was prepared by a woman – **J.T. Joblonski**

(for Maria Winkelmann)

Data coming from the above case studies have been studied and analyzed. In the current research report results are presented from:

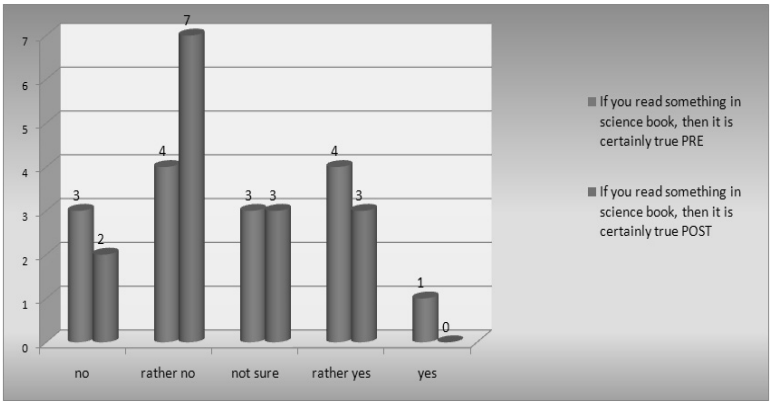
a) The distribution of the questionnaire before and after the implementation of the case studies.
b) The videotaped classroom activities.
c) The interviews that followed the implementation.

However, teaching material and material developed by the pupils was also analysed (worksheets, a short movie developed by pupils etc.)

Data analysis and results from the questionnaires

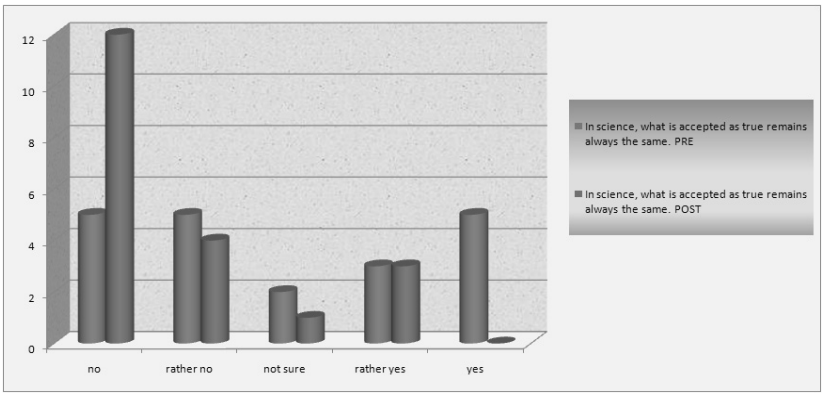
The questionnaire includes items that concern the nature of science (in the context of the GNOSIS Research Model) and items concerning classroom interaction and self-concept. Some comments about the various questionnaire items follow:

The nature of the science content



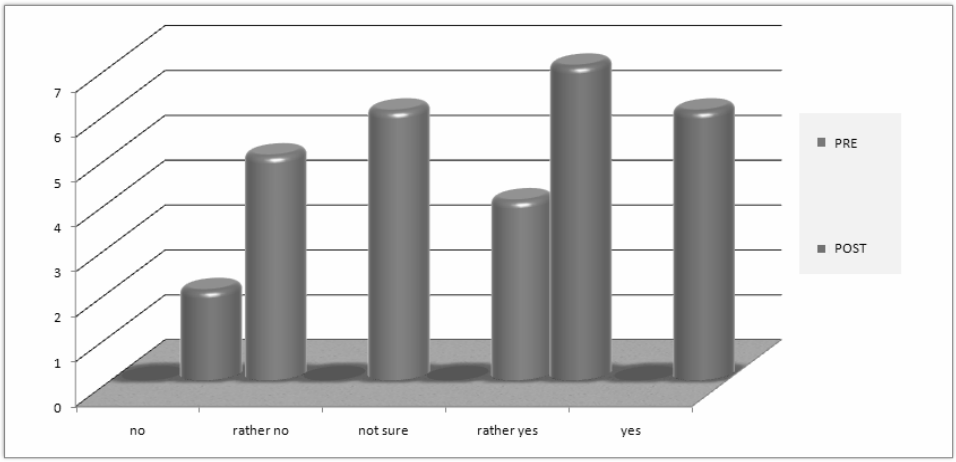
This is an example of the answers we get for one of the question concerning the nature of the science content. When asked "if you read something in a science book then it is certainly true" in-service teachers attending a post-graduate course consisting of Greek HIPST cases 4,5,6 (Galileo, Marie Curie and women astronomers) we see that after the teaching of the course we have a shift towards a more skeptic

and critical reading of science text books, as through the course a lot was discussed about the authenticity and the evolution of the recorded science knowledge in books.



The synthetic nature of science as a product

Here we have an example of the reaction of secondary education students attending the pendulum Greek HIPST case to a questionnaire item concerning the synthetic nature of science as a product. After the application of the HIPST case, the research population moves toward reconsidering whether “in science, what is accepted as true remains always the same” and most of them says “no” to the statements as during the pendulum HIPST case they became familiar to the change of ideas and theories concerning the study of pendulum in the past. To move beyond scientific dogmatism has been one of the goals both of the Greek HIPST cases as well as the teaching of nature of science.

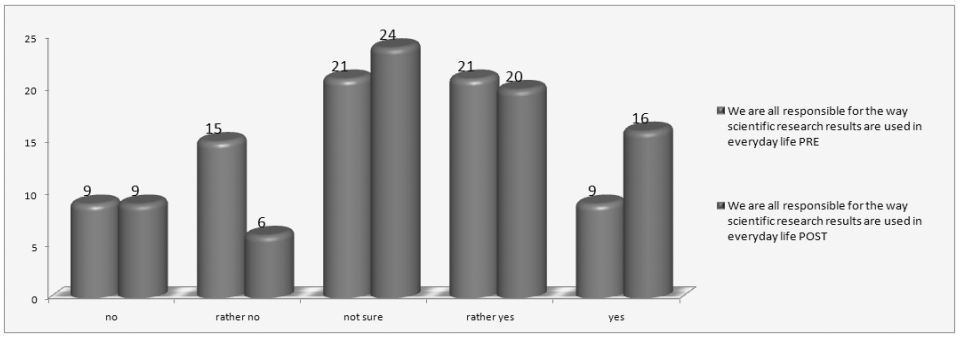


The nature of the evolution and methodologies of science

In the diagram above the results for the greek HIPST case about the geocentric-heliocentric debate are presented concerning pupils’ answers to the questionnaire item “Scientific explanations may change in time”. This is only an example of the effect of the HIPST cases on the understanding of the nature of the evolution and the methodologies of science. It is obvious that pupils that were not sure initially whether scientific explanations change in time, after the HIPST case have a clear opinion on the subject and most of them agree that scientific explanations change in time. The lack in the understanding of this aspect of the nature of science has been recorded as an obstacle in the learning of science, because the

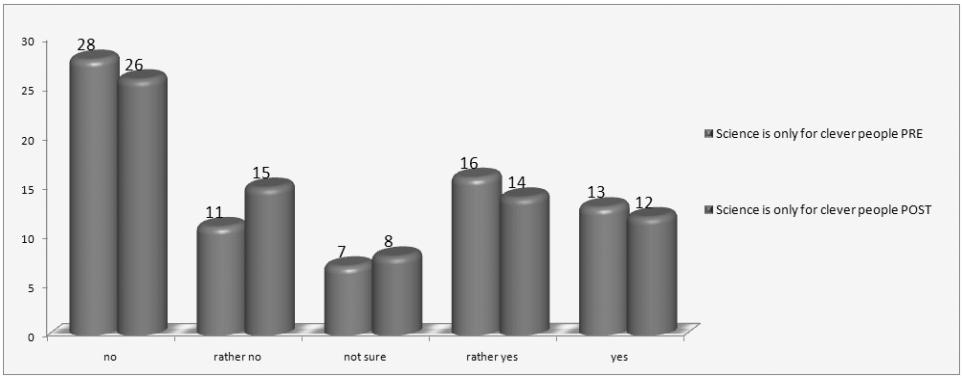
different explanations of the same physical phenomenon that comes from scientists of different eras confuse and stress pupils if they don't have this overall image of science as a network of explanations that are from time to time changed and improved.

The nature of the interrelations of science and society



The results shown above concern the questionnaire item: "we are all responsible for the way scientific results are used in everyday life" and come from the implementation of the greek HIPST case concerning the teaching of optics and the microscope inspired by Hook's "Micrographia". Pupils after the implementation move towards agreeing with the statement recognizing the transfer of knowledge, activities and products from science and society as well as the social effect on the contemporary use of all those in the communities of today.

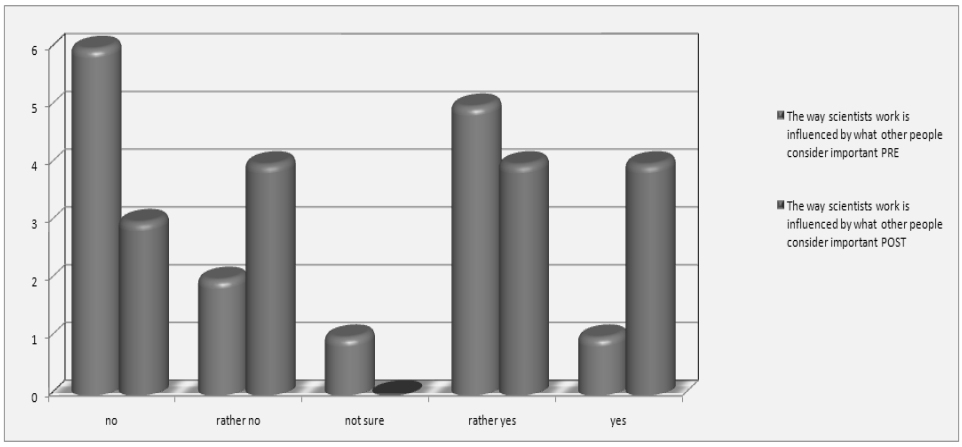
The nature of attitudes expressed through science



Concerning the attitudes expressed through science at the questionnaire item "science is only for clever people" we have a slight move towards 'no' at the results above coming from the Greek HIPST case about the teaching of optics and the microscope. In these category not much change has been recorded. This could mean that either the developed cases did not stress on these aspects or that the questionnaire items should be elaborated and checked again in next versions of the questionnaire.

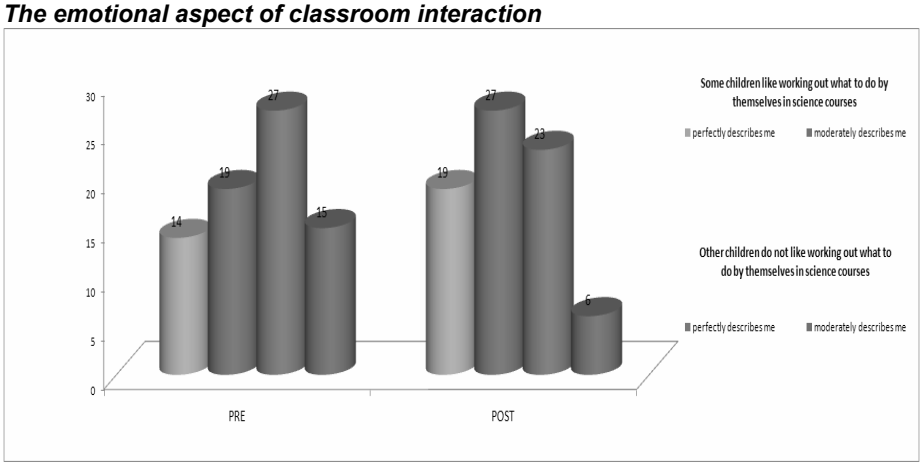
The nature of values fostered by science (in Part I of the questionnaire)

In the diagram that follows the results from the implementation of the greek HIPST cases about Galileo, Marie Curie and the women astronomers are presented concerning the questionnaire item "The way scientists work is influenced by what other people consider important".



The course of these three HIPST cases was attended by in-service teachers. At the diagram a clear move of the population from "no" towards "yes" is recorded. After the implementation most of the in-service teachers consider important the effect of people's values on the scientists' work putting science in the big picture of society.

The emotional aspect of classroom interaction



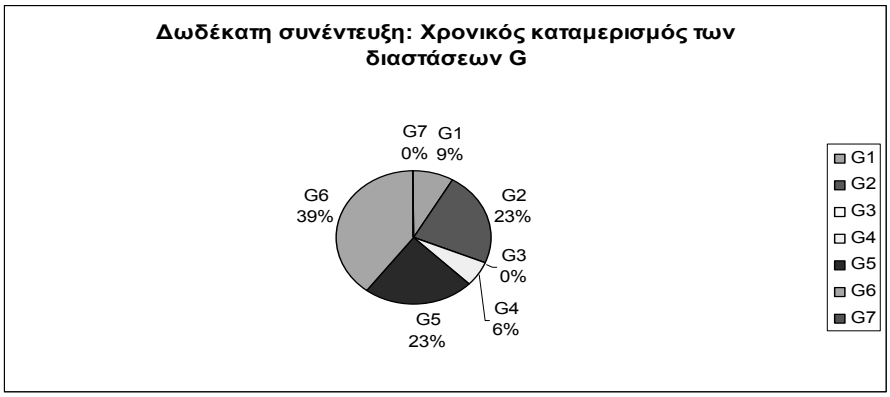
In the second part of the questionnaire at questionnaire item "some children like working out what to do by themselves in science courses" concerning the emotional aspect of classroom interaction, in the Greek HIPST case about the teaching of optics and the microscope we see that 11-year-olds move after the implementation towards a more independent attitude concerning science courses. They express their wish to decide on their own concerning the understanding as well the actions around a certain science topic taught.

Data analysis and results from the videotaped classroom sessions

During the application of the HIPST cases, also video recorded data were gathered and analyzed using the GNOSIS Research Model. Video recorded data were analyzed in each case by two individual researchers (and if needed also by a third one). The time line of the videotaped classroom activity was formed and the 7 GNOSIS aspects (G1, G2, G3, G4, G5, G6, G7) characterized the time periods depending on which nature of science aspect was recorded as more active in each time period. An example follows:

The above example is an extract from a role-play from the Greek HIPST case about the life and work of Marie Curie. The example shows the evolution of nature of science aspects in the discussion between

two teachers who perform the role-play and one pretends to be Marie Curie and the other a journalist who takes an interview from her. The part presented in the example is from the 220th second of the discussion till the 335th second of the discussion. It is recorded that the discussion has as a basis the nature of the content of science (G1) but it also makes gradual bridges to aspects concerning the synthetic nature of science as a product (G3), the nature of the evolution and the methodologies of science (G4), the nature of attitudes expressed through science (G6) and the nature of interrelations of science and society (G5) and closes with comments on the nature of science context (G2). This example shows us how two teachers discuss about science (in the context of the role play for this HIPST case) and the motive presented in their discussion moving from the cognitive to the meta-cognitive dimension of science learning twice and the from the cognitive to the emotional dimension finally returning to the cognitive could also become a teaching motive that could be incorporated in the teaching practices we develop for science education. This is only an example of the interesting and revealing information we can get from the video-taped HIPST cases.



The analysis of the time of a role-play by GNOSIS

In the implementation of the same HIPST case the analysis of a whole role play by GNOSIS provides the diagram presented above. During the role-play most of the time 39% was devoted to the nature of attitudes expressed through science (G6) and since the case is about Marie Curie this has been encouraged and women (and also immigrants) involvement in science and related attitudes were discussed. Also, a great deal of time was devoted to the nature of science contexts (G2) and the nature of science-society interrelations (G5). This analysis gives also a new perspective for what teachers consider important to learn about science: attitudes, context of science, science and society interaction. This information again is very important for science school practices and activities design.
Now, the analysis of all role-plays of this certain HIPST case by GNOSIS shows the following percentages of time devoted at each science learning dimension:

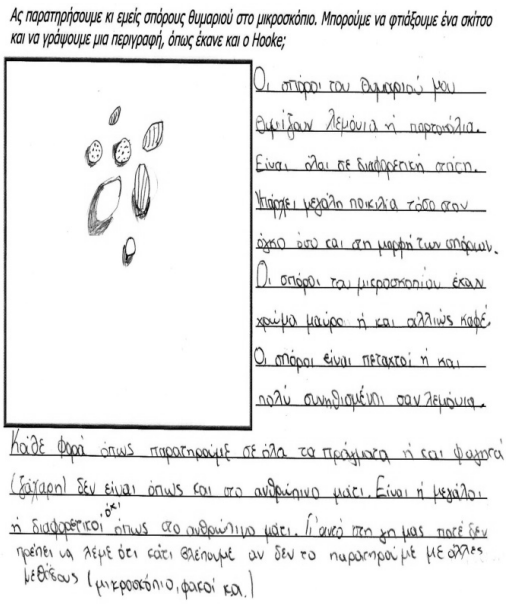
Dimension of science learning	Time devoted in all role-plays
cognitive	37%
metacognitive	29%
emotional	27%
cognitive-metacognitive	1%
cognitive-emotional	5%
metacognitive-emotional	1%

Many educators are afraid that if we start incorporating elements from the history and philosophy of science in science learning then perhaps there won't be much time for learning the content of science. It is clear in this case that most of time has been devoted to the content of science, furthermore discussing also the context around the content as well as the nature of both. At the same time the meta-cognitive and the emotional dimensions of learning science were also active and played an important role during this Greek HIPST cases. Teachers had the chance to discuss about the synthetic and the evolutionary nature of science and the interrelations of science and society as well as the attitudes and values fostered by science. This is an example of the contribution of the teaching proposals informed by the history and philosophy of science.

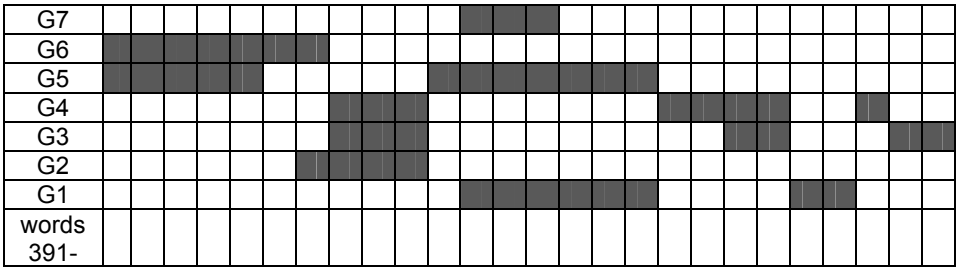
Also, worksheets that pupils worked with during the HIPST cases were analyzed using GNOSIS. The following worksheet is from the Greek HIPST case about the teaching of optics and the microscope.
The words of the texts of the worksheets were counted and a speech-line was created and analyzed by GNOSIS in a similar way as in the role-plays presented above.

G1	G2	G3	G4	G5	G6	G7
29 words	28 words	23 words	30 words	23 words	20 words	9 words

In the table the words of the pupils' text are counted and gathered in the GNOSIS categories. The nature of the content (G1) and of the context (G2), as well as the nature of the evolution and the methodologies of science (G4) take the most focus in the pupils' written essay. With 20-23 words each, follow the synthetic nature of science, the interrelations of science and society and the attitudes expressed through science. Last, with only 7 words reference comes the nature of values fostered by science. This example again verifies that activities in the context of HIPST cases contribute to a three-dimensional cognitive, meta-cognitive and emotional science learning and bring forward all aspects of nature of science.



Data analysis and results from the interviews that followed the implementation
In many cases, the implementation of the HIPST cases was followed by interviews with pupils. Here, we present an interview that followed the Greek HIPST cases about the geocentric-heliocentric debate. The interview was again analyzed using the GNOSIS model. A part of the interview is also presented here. Again a speech-line was created and analyzed (391st word to 520th word of the interview).



In the above table, it is shown that all seven nature of science aspects of the GNOSIS model were activated during the interview. Pupils not only expressed their appreciation of the HIPST case they attended

but also went on discussing about science referring to all three dimensions of learning science (cognitive, meta-cognitive, emotional) and all seven nature of science aspects (G1-G7). This recorded transferability of thinking and expressing oneself about science is a promising sign concerning the contribution of HIPST cases to science education.

Discussion

During the HIPST project, the developed HIPST cases were implemented to various populations (university students, student-teachers, in-service teachers, secondary education science teachers, secondary education pupils, primary education pupils and science museum visitors). In some of the above cases, data were recorded during and/or after the implementation. The research tools used to gather and analyze data were developed in the context of the GNOSIS Research Model, therefore a questionnaire and methods of analyzing written speech and video-recordings were developed. In the current research report many from the results coming from the implementation of HIPST cases have been presented. HIPST cases seem promising when one reads their theoretical framework and their proposals for teaching material and practices, however research has shown that HIPST cases can become even more promising and successful when applied in the classroom. Research results presented in this report show that when science is taught or presented in the context of HIPST, that is being informed by the history and philosophy of science, then an overall picture of science is provided to pupils, students and/or teachers and truly appreciated by them. This overall picture of science includes the nature of science content and contexts, the synthetic and evolutionary character of science, the nature of the methodologies of science, the nature of the interrelations between science and society, the nature of values and attitudes fostered by science. Also, since teaching is no-longer only content oriented but has a three dimensional cognitive, meta-cognitive and emotional character. And last but not least, learners are interested in the topics presented and seem motivated to be involved in such a learning of science. Of course, a lot remain to be done in the future. The HIPST project lasted 30 months and all researchers have contributed the best possible in this time period. Many HIPST cases will be improved and applied again in the future and new research data will be gathered. There is need for improving research tools, for gathering more classroom data, for analyzing in more detail and in comparative studies the effect of history and philosophy of science informed science teaching to various populations (students, teachers etc.). The current research has revealed a part of the matrix for understanding and evaluating the effect on learning of history and philosophy of science informed science teaching, remains to be further researched and documented in future research projects that will offer more answers, and hopefully even more research questions, to researchers in the field of history, philosophy and science teaching.

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