# INTRODUCTION OF HISTORY AND PHILOSOPHY OF SCIENCE ELEMENTS FOR CURRICULUM DEVELOPMENT

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## Abstract

Taking into account a progressive decline in pupil interest for science and technology education, especially physics education on different levels, from the secondary school to universities, in our paper as a kind of remedy, we put stress mostly upon pedagogy and the inquiry methods of pupils' teaching and learning, which are based on the attempts to introduce History and Philosophy of Science (HPS) into the school science curricula. Actually, we are collaborating with EU Colleagues from Germany, Greece, Portugal. Italy, Hungary, Israel and UK within the 7th FP on: „History and Philosophy in Science Teaching". There are three general objectives of HIPST Project: 1. To increase the inclusion of history and philosophy of science in science teaching for the benefit of scientific literacy. 2.To improve strategies for the development and implementation of domain-relevant materials, teaching and learning strategies into educational practice. 3. To strengthen the cooperation and establish a permanent infrastructure of sustainable networking of all involved stakeholders in the field of STL and public understanding of science (schools, museums, universities). First of all we wished to get more information on the state of art in the implementation of HPS in science teaching in Poland. Thus, we designed a special and comprehensive Questionnaire containing 18 tasks, which was sent to the Polish Association of Science Teacher members. The Questionnaire results are described in the paper. Furthermore, the methodology of work, the main products elaborated so far (as presentations, exhibitions, science lessons' scenarios, experimental resources - including replicas of historical experiments, eg. Witelo, Copernicus, Newton, Goethe, historical microscopes and spectacles) as well as the valuable means of the results dissemination are presented.

**Key words:** curriculum development, history, philosophy, science

## Introduction

It is widely acknowledged that there are serious problems with school science in many countries all over the world now. Such problems manifest themselves mainly in a progressive decline in pupil interest for school science across the secondary age range and by the fact, that only few students are choosing to study physical sciences at higher levels and as the careers (Sjöberg, 2003, Osborne and Dillon, 2007). Referring to the situation in Germany one can say: "Currently there are three main problems in physics teaching: Lack of interest for the school subject, lack of understanding of concepts, ideas and methods and lack of comprehension of the social and political role of science" (Rieβ, 2001). As the consequence, "scientific illiteracy" is growing and a reduction of democratic quality concerning decision making processes in regard to scientific and technological projects can be observed.
As the remedy to this situation we can find in the literature related to science education some proposals to reform mostly the programme of teachers' pre-service and in-service preparation (Turło, 2001, Lampiselkä J. Raykova Z., 2008), school work organisation, quality of the educational resources or the way of students assessment. We believe, that in spite of all these important factors any educational change in schools and in the society will take place in case of introduction of a new curricula, pedagogy and the inquiry methods of pupils' teaching and learning, especially that based on much more extensive use of History and Philosophy of Science (HPS).

In the years 1997-2001 Education of Physics Laboratory was the contractor and co-ordinator of the European, International Project PHARE/TEMPUS JEP-12267 on: „Modernisation of two-subject teachers training". One of the main Partner in this Project was The Research Group on Higher Education and History of Science at the University in Oldenburg, supervised by Professor Falk Rieβ. I their approach to improve science teaching, the role of the historical experiments is strongly emphasised (Herring, 1998, Rieβ, Heering, 1999), as experimental methods, are usually neglected by philosophers, historians and sociologists. Thus, this Group reconstructed and collected the biggest in Europe collection of historical instruments. Taking into account the opinion of Prof. Rieβ, that ***„due to the intensive course of the use of historical elements in science teaching we can achieve better understanding of Science contents and the Nature of Science (NOS) itself"*** in that time we started to follow the enrichment of science education by exemplary implementation of historical experiments into the teachers' training.

The most of produced replicas were based on the documentation provided by Oldenburg's Group (Turło, 2001) and made at our Institute of Physics workshop. The others (Witelo's experiments or Foucault's experiment) were designed and reconstructed by the physicists from our Institute of Physics (Turło, 2002). Thanks to this we were able to organise unique in Poland experimental workshops during the pre- and in- service teacher' training courses as well as to show the exhibition on: *„How experiments were made formerly?"* for North Poland community within Torun Science and Art Festivals and during XXXVI Conference of Polish Physical Society (Figure 1.).


**Figure 1. Exhibition: Experiments in the past.**

**Figure 2. "Witelon" at the exhibition FIAT LUX**

The below listed reconstructed instruments (see pictures below) were also presented during the Meetings of Polish Association of Science Teachers and during two meetings of General Polish Club of Demonstrators.

1. Instruments of Witelo (1230 – ca.1314) – the first proof of rectilinear motion of light and law of light reflection.
2. Galileo (1564 - 1642) inclined plane (channel)– discovery of the free fall law.
3. Sulphur sphere electrizer Otto von Guericke'a (1602 - 1686) – model of the Universe.
4. Electrophorus and Lichtenberg's (1742 - 1799) figures – mysterious forms of electric discharge.
5. Electrostatic machine – invention of electrostatics enthusiasts.
6. Leyda bottles of Musschenbroek (1692 - 1761) – spectacular containers of electricity.
7. Condenser electroscope of A. Volta (1745 - 1827) – the first estimation of electrostatics interaction.
8. Pile of cells A. Volta (1745 - 1827) and big battery (crown of cups) of Ritter (1776 - 1810) – the first effective source of electricity.
9. Weight of Coulomb (1736-1806) for measurement of electrostatic interactions
10. Thermoscope of Rumford (1753 – 1814) – towards contemporary theory of heat as the kind of motion.

11.Water prism of Goethe (1749 - 1832) – discovery of colour secrets.
12.Foucault (1819-1868) pendulum – „You are invited here to see how Earth is rotating!"

Since February 2008 we are collaborating with EU Colleagues from Germany, Greece, Portugal. Italy, Hungary, Israel and UK within the 7th FP on: „History and Philosophy in Science Teaching" under the supervision of Project co-ordinator – Prof. Dietmar Höttecke and Prof. Falk Rieβ. There are three general objectives of HIPST Project: 1. To increase the inclusion of history and philosophy of science in science teaching for the benefit of scientific literacy. 2.To improve strategies for the development and implementation of domain-relevant materials, teaching and learning strategies into educational practice. 3. To strengthen the cooperation and establish a permanent infrastructure of sustainable networking of all involved stakeholders in the field of STL and public understanding of science (schools, museums, universities).

**Methodology of Research**

*Questionnaire investigations*

At the beginning of our HIPST Project we wished to get more information on the state of art in the implementation of HPS in science teaching in Poland. Thus, we designed a special and comprehensive Questionnaire containing 18 tasks, which was sent to the Polish Association of Science Teacher members. 28 science teachers, mostly experienced (80% of nominated and diploma) secondary school teachers (45% - physics teachers) from different parts of Poland were taking part in the investigations on: "The HPS elements in science teaching". We were studying national situation regarding elements of HPS: **a)** Whether the elements of HPS were implemented to your pre- and in-service science teacher training courses?), **b)** Do you apply the elements of HPS in your science teaching?, **c)** If you selected NOT please give the reason why not, **d)** What should/can be the aim of the use of HPS in science teaching?, **e)** Point out the educational resources (source texts and other educational aids, which you are using in your professional practice and which can be used in the project HIPST (e.g. during the pilot lessons or during the collaboration of school with museum), **f)** Indicate the conditions and factors, which can facilitate (or inhibit) introduction of HPS elements to science teaching, **g)** What kind of knowledge and specific skills should teacher possess to succeed in introduction of HPS elements into teaching?, **h)** What features should characterize educational materials aimed at introduction of HPS elements into science teaching?, **i)** Please point out the core curriculum subject questions, which teaching could be supported by the elements of HPS **j)** Please present the propositions (ideas) of activities, which in your opinion allow to gain success in introduction of HPS into science teaching.

The main results of these studies will be presented in the next section.

*Organisation of work*

During the whole Project duration we decided to collaborate with **schools** from the surrounding area (which were represented by the teachers from lower and higher secondary school levels), with **museums and planetariums** as well as with **National Ministry of Education, Teacher Training Center in Warsaw and Regional Training Center** representatives. We established four working groups: **Group 1** - working on elaboration of materials and methodology of elements of HPS in secondary school teaching (including curriculum development) Expected outcomes: Report on „The place of HPS in new Polish

Core Curricula, Presentations on HIPST, Scenario of lessons and their realisation in school (pilot lessons)". We have created the common e-mailing list, all materials elaborated by the group members and consecutive actions are discussed and corrected by e-mails and during the face to face meetings (recently 1 per two weeks). **Group 2** - working on elaboration of teachers education and training programme with the HPS elements. Expected results: „Analysis of the *Philosophy of science* subject existing so far for the pre-service science teacher training and elaboration of the corrected one". **Group 3** - working on elaboration of materials and on practical realisation of exhibitions and collaborating with Regional Museums on activities related to HPS. Expected outcomes: **a)** Designing and practical realisation of the „FIAT LUX – from Witelo to optical tomography" interactive exhibition in the Regional Museums Torun (see Figure 2.) and at: http://dydaktyka.fizyka.umk.pl/FIAT_LUX/html, in Hevelianum, Gdansk, Planetarium, Olsztyn and in Legnica, where Witelo was born. **b)** The sustainable network of University, Regional Museum and Planetarium in Torun and Hevelianum Center in Gdańsk establishment with Prof. Karwasz as the co-ordinator. **Group 4** - working on designing of replicas of historical experiments and materials suitable for the use in school, university and out of school education **–** Expected results: „Reconstruction of the Copernicus simplified astrolabium, Galileo telescope and Witelo device for plotting conical curves (from our resources).

## Results of Research

*Questionnaire studies*

Below we will present selected, exemplary results of the studies (answers to the Questionnaire questions) related to the national situation regarding elements of HPS*:* „Whether the elements of HPS were implemented to your in-service science teacher training courses?" (Q 8). „Do you apply the elements of HPS in your science teaching?" (Q 9).

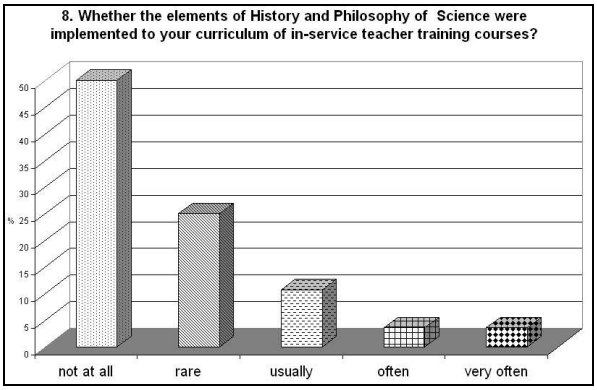


**Figure 3. The answers to the Question Q8.**

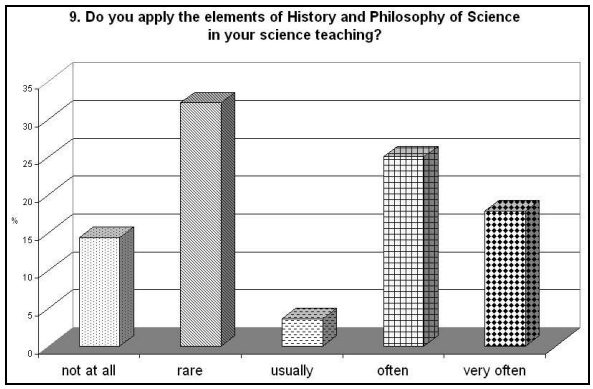


**Figure 4. T he answers to the Question Q9.**

If in Q9 You have selected NOT, please give the reasons why you are not using HPS in science teaching? (Q11). The answers to this question are presented in the Figure 5.

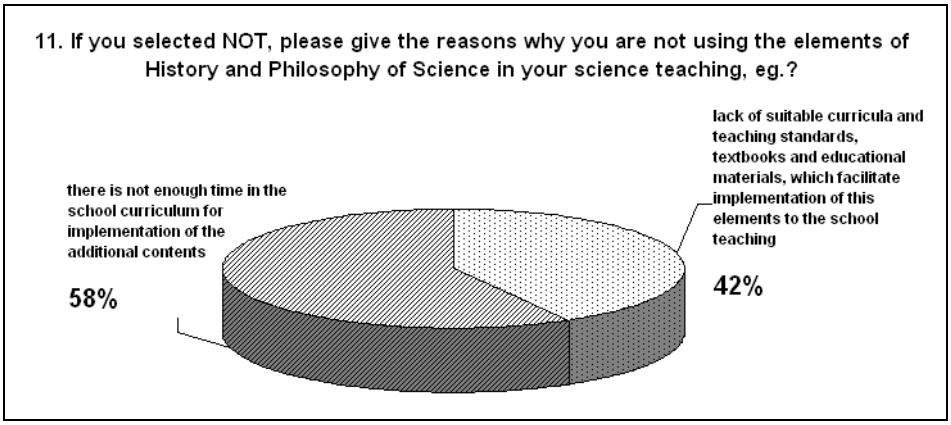


**Figure 5. The answers to the question Q11.**

**Table 1. The answers of science teachers to the question Q12.**

| No. | Answers to Q12: "What should/can be the aim of the use of HPS in science teaching?" | % |
|---|---|---|
| 1. | to emphasise that knowledge of science and history of science is the important part of our culture | 64 |
| 2. | to recognise the methods and character of scientific research | 54 |
| 3. | to stress the ethical values of science | 18 |
| 4. | to achieve the skills of planning and executing of experiments, especially hands-on experiments | 43 |
| 5. | to increase interest and motivation of students | 61 |
| 6. | to increase the students' activity during lessons | 46 |
| 7. | to raise the science teaching effectiveness | 32 |
| 8. | to understand the applications of science in context (technics, everyday life) | 57 |
| 9. | to perceive the role of science in personal life (health, diet, saving of energy) | 29 |
| 10. | to gain the skills of discussion on science topics with others | 21 |
| 11. | to know the origin of preconceptions and misconceptions of students | 11 |
| 12. | to include interdisciplinarity in science teaching | 54 |
| 13. | to get the ability of information judgement (received from different sources) | 25 |
| 14. | others | 4 |

**Table 2. The answers of science teachers to the question Q14.**

| No | Answers to Q14: "Indicate the conditions and factors, which can facilitate (or inhibit) introduction of HPS elements to science teaching." | % |
|---|---|---|
| 1. | essential (subject), methodical and technical preparation of teacher | 79 |
| 2. | allowance of HPS issues in pre-service and in-service teacher training standards | 50 |
| 3. | elaboration of general strategy aimed at the use of HPS elements in science teaching | 32 |
| 4. | collaboration of science teachers with experts conducting research in the HPS field | 46 |
| 5. | accessibility of the high quality educational materials | 75 |
| 6. | HPS topics included to the school curricula and final examinations | 46 |
| 7. | the attitude of teacher and administration support in the use of HPS in teaching | 29 |
| 8. | others | 7 |

**Table 3. The answers of science teachers to the question Q15.**

| No | Answers to Q15:"What kind of knowledge and specific skills should teacher possess to succeed in introduction of HPS elements into teaching?" | % |
|---|---|---|
| 1. | skill of carry on lessons by active methods, including inquiry method | 61 |
| 2. | skills of writing scenarios and directing students' historical performances („role playing") | 46 |
| 3. | skill of telling interesting stories | 57 |
| 4. | skills of persuading (argumentation) and leading of scientific discussions | 46 |
| 5. | skill of the use of Information and Communication Technology resources | 54 |
| 6. | others | 11 |

**Table 4. The answers of science teachers to the question Q16.**

| No | Answers to Q16: "What features should characterize educational materials aimed at introduction of HPS elements into science teaching?" | % |
|---|---|---|
| 1. | „user friendly" (as far as contents and structure (form) is concerned) | 57 |
| 2. | adjusted to the needs of teacher, as well as the age, capabilities and abilities of students | 89 |
| 3. | including scenarios of „inquiry lessons" based on HPS elements | 46 |
| 4. | diverse and adapted to the local conditions | 39 |
| 5. | commonly available | 43 |
| 6. | others | 0 |

*Conferences, seminars, workshops*

We took a part in the kick-off meeting in Florence in February 2008, where was decided to organise the national HIPST meeting and elaborate the national work plans by each country participating in HIPST Project.

The first national meeting in Toruń was held on 12th September 2008. Forty two participants were attended. During this meeting we had opportunity to discuss the details of national work plan of the project with teachers and experts. Taking into account the future plans of work, he schedule of the meeting was as follows:

- Dr. Józefina Turlo, Introduction to the Project HIPST.
- Lecture of Professor Andrzej Bielski on: "Witelo, the first Polish nature scientist from XIII c., having international reputation".
- Lecture of Professor Lech Bieganowski and professor Janusz Mallek on*:* "Invention of spectacles in Europe".
- Lecture of professor Grzegorz Karwasz on: "Practical realisation of interactive exhibition on OPTICS" (including the optical historical experiments, e.g. Witelo, Copernicus, Galileo, Goethe)".
- Dr. Józefina Turło, Presentation of the science teachers Questionnaire study results on: "The HPS elements in science teaching".
- Research group establishment, discussion in groups, plan of work propositions, summary. Furthermore, the members of particular groups are meeting and discussing the actual problems.

*The main HIPST products and their dissemination*

- The first list of teaching materials were identified by the Torun Partner Group members and by the Questionnaire answers of science teachers. Some were described.
- To start with proposition of HPS elements implementation into science curricula, first of all new Polish physics core curricula (obliged from 1st September 2009) for lower and higher secondary school have been analysed. The experienced science teachers prepared the comprehensive documents indicating which topics could be supported by introducing HPS elements and placed them at the Polish web page of HIPST project.
- To improve strategies for the development and implementation of selected materials from optics, related to e.g. Witelo (Bieganowski et al.,1991, Bielski et al.,2006), Copernicus (Sniadecki, 1953, Przypkowski, 1958, Sikorski, 1993) Newton, Goethe experiments, historical microscopes and spectacles (Bieganowski, 1980) into school curricula the teachers started to elaborate scenarios of the inquiry-based lessons (Olson, 2000). The first scenarios are ready already and the first lesson on historical spectacles was taking place in the higher secondary school in Torun.

- Two groups of teachers (one in the secondary school and the second at the Institute of Physics are performing original Nicolaus Copernicus experiment on „Time measurements" by using the sun reflection method, trying to plot historical „astronomical table" as that below (Figure 6), which one can find at the Olsztyn castle (Cygański,2006).

**Figure 6. The photo of „astronomical table" placed at the Olsztyn castle**

- To intensify these activities we ask our three students - science teachers to be to collaborate with practising teachers and us on HIPST issue. There are the topics: 1. Active methods for motivation students towards effective learning of physics 2. Proposition of physics teaching enriched by HPS implementation 3. Development of inquiry - interactive methods of teaching based on Witelo and Copernicus historical experiments.
- The cooperation was strengthened and a permanent infrastructure of sustainable networking of all involved stakeholders in the field of scientific literacy and public understanding of science (schools, museums, university) was established.
- Especially, the interactive exhibition on "FIAT LUX – from Witelo to optical tomography" was exposed from 29 April until 15th September at the Regional Museum in Toruń. Exhibition contains among others the replicas of historical experiments as: Witelo devices, Goethe prism, many kinds of historical spectacles, Copernicus instruments, set of historical telescopes, etc. This exhibition was also exposed in the Hevelianum Center in Gdańsk (20.10.08 - 15.02.09*)*, and now, since 1st of March is presented in the Olsztyn Planetarium. Before the FIAT LUX exhibition in Torun Museum there was local training session for 25 science teachers from the Region organised, in Gdansk two training sessions (for teachers and staff at Hevelianum Centre) were organised, but in Olsztyn 4 training sessions are planned (one devoted to public).

  The „FIAT LUX" exhibition in Torun have been seen by about 14 000 visitors (including 50 classroom students), in Gdańsk there was 5 400 visitors- mostly school students.
- Generally, the acceptance of the FIAT LUX exhibition was very good, but unfortunately rather trivial. Therefore, the much more detailed descriptions and evaluation tools are desired. We expect to change the attitude of students to the essential values of such exhibitions as well as to enhance their Scientific Literacy.
- As the some resources are presented at the exhibitions, there are not available to the teachers at schools.
- We would be interested in the further development of the exhibition's collection, especially we would like to construct replicas of some others historical telescopes (the Galileo telescope was already constructed from our resources) as well as to propose school pupils' activities concerned with Copernicus astronomical table reconstruction.
- the Regional Seminar for science teachers on education of science, including HIPST problems has been established.
- Selected educational materials on HIPST Project are systematically placed at the Polish www page of HIPST: **(http://hipst.fizyka.umk.pl).**

**Discussion and Conclusions**

From the answers of science teachers to the question Q8 (see Figure 3.) we can conclude, that elements of HPS in their in-service courses are used only rare or not at all (more than 70 % answers) and about a half of them are not implementing HPS in their teaching (Q9 – see Figure 4.). As the reasons why they were not using HPS in science teaching? (Q11) they quoted (see Figure 5.): "lack of suitable curricula and teaching standards, textbooks and educational materials, which facilitate implementation of HPS into science teaching"(42%) or "there is not enough time in the school curriculum for implementation of the additional contents" (58%).

Investigated teachers have given comprehensive answers to the Question 12 (see Table 1.) In their opinions the use of HPS in science teaching should be mostly aimed at:
1.emphasising that knowledge of science and history of science is the important part of our culture, 2. increasing interest and motivation of students, 3. understanding the applications of science in context (technics, everyday life), 4. recognising the methods and character of scientific research 5. including interdisciplinarity in science teaching, 6. to raising the science teaching effectiveness, 7. achieving the skills of planning and executing of experiments, especially hands-on experiments. But they are not emphasising the possibilities to know the origin of preconceptions and misconceptions of students, to stress the ethical values of science or to get the ability of information judgement (received from different sources).

Identifying the conditions and factors, which can facilitate (or inhibit) introduction of HPS elements to science teaching" (Q 14) they mainly indicated (see Table 2.): subject, methodical and technical preparation of teacher, accessibility to the high quality educational materials, presence of HPS issue in pre- and in-service teacher training courses as well as incorporation of HPS issue to the school curricula and final examinations.

Answering for the question 15 (see Table 3.) they think, that to succeed in the introduction of HPS elements into science teaching teacher should posses mostly the skill of carry on lessons by active methods, including inquiry method, skill of telling interesting stories, ability to use ICT resources, to write scenarios and supervising students' historical "role playing", as well as skill of persuading and leading of scientific discussions.

But with respect to the educational materials devoted to HPS elements (Q.16) they would like to have them (see Table 4.): adjusted to their needs and to the age and capabilities of students, including scenarios of "inquiry lessons", "user friendly", commonly available and adopted to the local conditions.

The question Q18 was as follows: "Please present the propositions (ideas) of activities, which in your opinion allow to gain success in introduction of HPS into science teaching." Below we are quoting the most interesting, exemplary propositions:

1. Practical investigations (on-line experiments), e.g.:
   - study of motion with the use of historical Galileo's incline plane,
   - measurement of velocity (frequency) of sound by different means,
   - study of electrostatics phenomena with the use of balance weight,
   - reconstruction of different electrical measurements,
   - demonstration of the most important historical experiments from optics,
   - construction of simple electrical and optical instruments by students.
2. To place the HPS elements on the science curriculum, but taking into account the local conditions.
3. Study visits of teachers and pupils at science museums.
4. Pre-service and in-service teacher courses (workshops) on HPS (Allchin et al.,1999).
5. Edition of booklets (books) for teachers (with exemplary propositions).

6. The use of inquiry methods concerned with HPS elements combined with „brain storming" and „role playing".
7. Collaboration of science teachers with teachers of history, literature, philosophy, ethics, religion, etc.
8. Dissemination of the project results in different tools (collection of scenarios, journals, films, www, TV, newspapers, etc.) and especially to maintain HIPS web page.
9. Organisation of the national and Regional Conferences and workshops on HIPST in Poland and lecture with demonstration on historical experiments for students.
9. Organisation of competitions: for teachers on: „Proposition of the most effective use of HPS in science teaching" (scenario of lesson or/and historical experiment), for students on: „Construction of simple historical experiment/model with the use everyday materials" and on: „Presentation of performance related to important discoveries in science".
10. Establishment of periodic seminars on HPS for science teachers.
11. Founding the Real Science Museum with on-line, interactive, (including distance) experiments.

As we can see from the above summary of our study results we are still far away from the final realisation of our ambitious HIPST project. However, we are lucky to collaborate with EU colleagues, who have much longer experience in introduction of HPS for science curricula development as Germany (Rieβ, 2001) Greece, Israel, Italy, UK (Hodson 1988, Monk and Osborne, 1977). History in science in the national curriculum in the UK was described for example by Dr. Martin Monk. He is writing: "In the 1999 version of *Science : National Curriculum for England* there is stated under the heading of *Ideas and evidence in science* for 11-14 year olds: Students should be taught: a) about the interplay between empirical questions, evidence and scientific explanations using historical and contemporary examples, b) that it is important to test explanations by using them to make predictions and by seeing if evidence matches the predictions, c) about the ways in which scientists work today and how they worked in the past, including the roles of experimentation, evidence and creative thought in the development of scientific ideas" (Monk, 2001). We agree with the educational model based on constructivism theory, which was elaborated by Hodson, Monk and Osborne, which assume that: "A place can be found for the history of science if the general pedagogic strategy in science education shifts from being didactic (understood as lecturing by a native speaker) to being discursive". He was inspired by Eric Rogers book ideas on: "Physics for Inquiry Mind" (Rogers, 1960).

In our work on the exemplary HPS based curricula material we are also looking for elaboration of the most effective methods for teaching and learning fascinated, interdisciplinary science for "inquiry minds".

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**References**

Allchin D., Anthony E., Bristol J. et al., 1999, History of Science- With Labs, *Science*

*Education* 8, 619-632.

Bieganowski L., Bielski A., Dygdała R. S., Wróblewski W., 1991, Witelona Perspektywy, Księga II i III, *Studia Copernicana*, t. XXIX, Ossolineum, Wrocław.

Bieganowski L., Małłek J., 1980, Przyczynek do historii chirurgii okulistycznej w Polsce w XVI w. Kwartalnik Historii Nauki i Techniki, R.XXV -2.

Bielski A., Bieganowski L., 2006, Zarys tradycji Witelońskiej w literaturze nauk przyrodniczych, ANALECTA R.XV, z.1-2, *Studia i Materiały z dziejów Nauki*.

Cygański Janusz, 2006, Astronomiczna tablica Mikołaja Kopernika, *Spotkania z zabytkami*, 11.

Herring P. ed. 1998, Welt erforshen – Welten konstruieren, Physikalische Experimen-tierkultur vom 16. bis 19. Jahrhundert, *Isensee-Verlag* Oldenburg.

Hodson D., 1988, Towards a philosophically more valid science curriculum, *Science Education* 72.

Lampiselkä J., Raykova Z., 2008, EU TRAIN Towards a Common Curriculum for the Teaching Practice of Science Teachers, *University of Helsinki*.

Monk M., 2001, Using the history of science in science teaching, *Proceedings of Science and Mathematics Teaching Conference in Toruń*.

Monk M., Osborne J., 1977, Placing the history and philosophy of science on the curriculum: a model for the development of pedagogy, *Science Education* 81 (4): 405-424.

Olson S., Loucks-Horsley S., 2000, Inquiry and the National Science Education Standards: A Guide for Teaching and Learning, NRC, *monograph online*, April 2009, http://www.nap.edu/catalog/9596.html.

Osborne J. Dillon J., 2007, Science Education in Europe: A Strategy for the Future, *ESERA Conference, Malmo*, and 2008, Science Education in Europe: Critical Reflections, A Report to the Nuffield Foundation. London, King's College.

Przypkowski T., 1958, Astronomiczne zabytki Olsztyna, *Rocznik Olsztyński* str. 135-172,

Rieβ F., 2001, Historical Experiments – a modern approach to physics teaching?, *Proceedings of Science and Mathematics Teaching Conference in Toruń*.

Rieβ F., Heering P., Reader zum demonstrationspraktikum fur alle lehramter, *Oldenburg University*, Physics Dept., 1999.

Rogers E., 1960, Physics for the Inquiring Mind, Princeton, *NY: Princeton University Press*.

Sikorski J., 1993, *Komunikaty Mazursko-Warmińskie*, Olsztyn, str. 131-166.

Sjöberg S., 2003, Science and Technology Education: A High Priority Political Concern in: Europe in Science Education Research in the Knowledge Based Society (*Utrecht, the Netherlands, Kluwer*) p. 211.

Śniadecki J., 1953, O Koperniku, Warszawa, str.105-106.

Turło J. ed., 2001, Eksperymenty historyczne w nauczaniu fizyki, *TopKurier*, Toruń

Turło J., 2001, Modernisation of two-subject physics and mathematics teacher educatio*n* in Pinto R. and Surinach S., ed. Physics teacher Education Beyond 2000, Paris cedex 15: *ELSEVIER*.

Turło J., Służewski K., Rybicki J., Karbowski A., 2002, Przykłady wykorzystania eksperymentów historycznych w nauczaniu fizyki, *Fizyka w Szkole*, t. 262, ss. 62-72.