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Why Implementing History and Philosophy in School Science Education is a Challenge: An Analysis of Obstacles

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Abstract Teaching and learning with history and philosophy of science (HPS) has been, and continues to be, supported by science educators. While science education standards documents in many countries also stress the importance of teaching and learning with HPS, the approach still suffers from ineffective implementation in school science teaching. In order to better understand this problem, an analysis of the obstacles of implementing HPS into classrooms was undertaken. The obstacles taken into account were structured in four groups: 1. culture of teaching physics, 2. teachers' skills, epistemological and didactical attitudes and beliefs, 3. institutional framework of science teaching, and 4. textbooks as fundamental didactical support. Implications for more effective implementation of HPS are presented, taking the social nature of educational systems into account.

1 Introduction

Teaching and learning science with history and philosophy of science has a long tradition in several countries (e.g. Martins 1990; Matthews 1994; Höttecke 2001). Science educators often have stressed the merits of this approach for teaching and learning about science as a process (e.g. Millar and Driver 1987; Matthews 1994; Allchin 1997a), for promoting conceptual change and a deeper understanding of scientific ideas (Wandersee 1986; Sequeira and Leite 1991; Seroglou et al. 1998; Van Driel et al. 1998; Galili and Hazan 2001; Pocovi and Finley 2002; Dedes 2005; Dedes and Ravanis 2008), for supporting learning about the nature of science (NoS) (Solomon et al. 1992; McComas 2000; Irwin 2000; Lin and Chen 2002; Fernández et al. 2002), for fostering public understanding of science (Solomon 1997; Osborne et al. 2002), and for positively impacting students' attitudes and interests toward science (Kubli 1999; Heering 2000; Solbes and Traver 2003;

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Mamlok-Naaman et al. 2005). History of science can also provide role models of female scientists to enhance girls' attitudes towards science (Allchin 1997a; Heering 2000; Solomon 1991; Höttecke 2001). Since science education is also a part of general education, arguments have been made that the history of science contributes to science for citizenship (Kolstø 2008).

All these expectations and benefits assigned to HPS sharply contrast with its apparent lack of significance for most of science teachers and curriculum developers. Science textbooks rarely address in a meaningful way the historical development of science and the nature of science, instead presenting science in a distorted and a-historical way (Pagliarini de and Silva 2007; Abd-El-Khalick et al. 2008; Irez 2008). Monk and Osborne (1997, p. 407) therefore conclude "[a]ttempts to produce structured courses that put history at the center of the enterprise […] have enjoyed only marginal success". One major reason for the low degree of implementation of HPS in school science education is that many advocates of history and nature of science in science education fail to consider the complexity of educational systems in which HPS related curricular innovations should be implemented.

The general problem of how to connect curricular innovation with teaching practice becomes evident for implementing HPS approaches like any other curricular innovation. Generally speaking, teachers are the gatekeepers of their classrooms and curricular innovations. Thus, their perspectives and potentials hinder or enable and shape the process of implementation. A curricular innovation recommended to practitioners can differ substantially from the curricular innovations enacted by them (Reinmann-Rothmeier and Mandl 1998). A principal reason for that is that researchers and curriculum designers, on one side, and practitioners on the other generally suffer from a "difference in norms, rewards and working arrangements" (Huberman 1993, p. 2). Hence, the process of implementing a curricular innovation like HPS should consider how practitioners could be supported and enabled to relate the innovation designed to their every-day practices (Heilbron 2002; Clough 2006) and skills as well as to their beliefs about teaching, learning, epistemology, curriculum and the general role of innovations.

The present paper is concerned with an analysis of obstacles that interfere with effective implementation of HPS in school science teaching, focusing on the objective of learning scientific concepts and about the nature of science (NoS). Our analysis mainly focuses on physics teaching and learning on school level, although the teaching of physics and science are not easy to separate from each other. A deeper understanding of science teachers' hesitation or even refusal of teaching science with HPS is a prerequisite for developing high quality HPS teaching materials that teachers will use. Knowledge about the requirements for teachers' professional development towards teaching HPS in science teaching has to be based on such an analysis. In order to be successful, current and future projects on developing curricular innovations integrating HPS have to consider these obstacles and how to cope with them.

2 Status of Implementation of History of Science in Physics Education

In order to analyze the current state of implementation of HPS in science teaching, national conferences in several countries have been held within the framework of a European project called HIPST: *History and Philosophy in Science Teaching* (Höttecke and Rieß 2009; see also http://hipst.eled.auth.gr). The project, comprising the effort of ten groups from seven European countries and Israel, aims to promote a more effective approach to implementing HPS in science education. The HIPST project is mostly concerned with the development and implementation of case studies for teaching and learning science with HPS in close collaboration with teachers. The materials are developed, evaluated and refined within a collaborative developmental model. The effort brings together researchers and practitioners' perspectives on HPS and science teaching in order to develop research-based curricular innovations with a high degree of adequacy from both perspectives involved. Based on their experiences, experts from science education, science museums, science teaching and school science administration analyzed the status of implementation during national conferences held in several European countries.[1]

Results summarize central problems of implementation: participants of the conferences criticized a lack of a sustainable concept of how to implement HPS properly in science teaching in their countries. Partners pointed out that a "usual science teacher" is very often neither interested nor competent in teaching HPS; those teachers who actually make use of HPS are uniquely interested in HPS and motivated to convey HPS to their students. The participants of national conferences also agreed that teachers usually have no clue of how HPS might help to teach scientific content, while teachers regard the latter as the most important objective of their own teaching. Similar results were found in projects conducted elsewhere (Lakin and Wellington 1994; Clough 2006, 2009; Clough et al. 2009). In general, there is a lack of teaching skills necessary for a successful HPS approach as inquiry based teaching (mentioned as a part of the HIPST project), storytelling, writing role-play scenarios and directing students' performances, or moderating open-ended discussions among students. History is restricted to an introduction of a new topic. It serves for instance as an anecdote or introductory underline of a new scientific model (e.g. model of atoms) with a historic background.

Moreover, attendants of the national conferences stressed that HPS has no important role in official science curricula, textbooks and educational material. Other factors interfering with HPS instruction include an overstuffed curriculum that leaves little space for the HPS, a lack of high quality HPS instructional materials, and an insufficient link between HPS and science content in textbooks. Conference participants noted that HPS, if implemented at all, is often restricted to a trite contrast with recent more elaborated ideas.

To sum up, developing strategies for implementing HPS in school science that are widely accepted and support by teachers is a huge challenge. What are the reasons? In order to develop an answer to this question, this paper analyzes in detail obstacles for bringing HPS into the classroom focusing on four relevant aspects:

- A culture of teaching physics that differs from other cultures of teaching other school subjects;
- Skills, attitudes and beliefs of physics teachers about teaching physics and epistemology;
- Institutional framework of science teaching with special focus on curriculum development;
- A lack of adequate HPS content in textbooks.

These four aspects mirror the main obstacles of implementing HPS stressed by the expert-meetings of national conferences in the HIPST project. The following paragraphs

[1] Reports on national conferences cited here have been thankfully provided by P. Brenni (Fondazione Scienza e Tecnica, Florence, Italy), D. Höttecke (University of Bremen, Germany), I. Galili (Hebrew University of Jerusalem, Israel), R. Coelho (University of Lisbon, Portugal) and J. Turlo (University of Torun, Poland).

analyze these obstacles based on research literature and a systemic view on German and Brazilian standard documents.

3 The Subject Culture of Teaching Physics

Efforts for implementing history and philosophy in physics teaching cannot ignore the perspectives of teachers, their beliefs about teaching and learning, their major goals and ideas on teaching and learning as well as their epistemological understanding. In order to analyze physics teaching as a culture, in this section we consider norms and values as well as socially shared practices indicated by the research literature (Hericks and Körber 2007; Willems 2007):

- Ways and styles of communication and interaction in the classroom
- Norms and values relevant for teaching and learning
- The content knowledge which teachers regard as relevant for learning physics
- Typical ways of running a lesson.

We call a culture of teaching a specific school subject like history, physics or mathematics a subject culture. It is constructed by noticeable features which embrace teachers, who are immersed in that culture, and strongly affects their curricular decisions and instructional behavior (Munby et al. 2000; Aikenhead 2003; Osborne et al. 2003; Willems 2007). Subject cultures comprise the entirety of characteristics of a subject like typical processes and methods of teaching and learning, repeated instructional strategies, content regarded as mandatory or add-on, as well as expectations, accepted or rejected habits and curriculum emphases (Roberts 1982) of its members. Being a teacher immersed in a specific subject means participating in a socially shared practice of objectives, relevant content and instructional designs. Subject cultures affect students' interests while corresponding with their self-image (Taconis and Kessels 2009).

In a recent comparative study conducted in Germany about different cultures of teaching language and physics, Willems (2007) demonstrates that physics teachers define their primary objective of teaching as conveying the truth about nature. An extraction of an interview of a physics teacher illustrates this statement:

> And in physics teaching it is very important to explain things, to develop models for something, to illustrate something. […] *the major objective is to express something very clearly.* […] But in English teaching it matters more how you express something. In English teaching things are *less definite, right or wrong*. You can have *different opinions* on a topic. (Willems 2007, p. 167, our own translation, emphasis added)

In contrast to an English teacher, a physics teacher appears as someone who expresses definite knowledge clearly. While in English classes different opinions do matter, different opinions, instead, are regarded as less important in physics classes. Osborne and Collins (2001) indicated similar findings in an interview study with school students, where they found that science is regarded as a subject with "less margin for error". Consequently, the authors indicated school science to offer little to those students interested in expressing themselves. Physics teachers regard the content to be taught as truths about nature that must be conveyed to their students as a collection of facts (e.g. Aikenhead 2003; Osborne et al. 2003). This means that they do not understand content as a matter of discussion and negotiation among their students. Therefore, memorizing scientific facts is an important aspect of teaching physics. Video-analysis of physics lessons has also shown that memorizing facts during physics lessons is actually more important than teachers themselves admit (Reyer et al. 2004). According to students' perspective, science is essentially regarded as a body of knowledge characterized by facts, which have to be learned. Therefore, compared to other subjects taught in school, science is rarely appreciated as a creative endeavor (Osborne and Collins 2001). The belief that science is lacking creativity has also been indicated for pre-service science teachers (Aguirre et al. 1990; Abell and Smith 1992; Irez 2006). Accordingly, scientific ideas appear as something given, without providing opportunities to students to develop deeper insights into the reasons for regarding a scientific assumption to be true. The following citation highlights perspective of students:

> In history, I mean, certain events, you ask why they happen; sometimes they actually backtrack to why it happened. I mean with science it's just, 'It happened, accept it, you don't need to know this until A level' (Student cited by Osborne & Collins 2001, p. 454).

Regarding the manners and styles of communicating and interacting with their classes, Willems (2007) found out that physics teachers believe that their students do need and want clear guidance. Brickhouse and Bodner (1992) reported similar findings. They investigated second-year middle school science teacher's beliefs about science and science teaching and how these beliefs influence classroom instruction. There is the view of science as creative opposed to the view of science teaching to be a highly structured in order to support students' learning. Physics teachers' view on students as wanting to be guided fits very well with how they regard the content of the discipline they teach.

Physics teachers also have a tendency to structure their lessons strongly. Typical scripts of physics lessons are teacher-centered and teacher-dominated (Tesch and Duit 2004). Thus, physics teachers have a strong orientation towards making their lessons running smoothly and according to the lesson plan. Even though they stress the importance of students being active during their lessons, they do not understand students' activities as active learning, but as being busy (Fischler 2000). A lack of competence for moderating discussions and negotiations among students may be one of the explanations for teacher's behavior (Driver et al. 2000).

Osborne et al. (2002) during their analysis of a new course focusing public understanding of science and including HPS aspects describe the disciplinary culture as a familiar territory for many teachers, with which they feel at ease:

> In short, these teachers are moulded by the culture of the discipline and activity in which they have engaged, often for many years. Breaking that mould is neither straightforward nor simple (Osborne et al. 2002, pp. 30f).

The stability of the culture of teaching physics may be best explained by the rewards teachers in this field usually gain by their strong focus on science as a body of knowledge. Usually science teachers are deeply socialized into their disciplinary field while participating in teacher training-courses. Their affinity to their discipline is even stronger, if they had participated in a teacher-training program for secondary and uppers secondary level. Their professional self-image as a science teacher is related to the structure and character of the discipline as knowledge and even fact centered. There they

> […] are certified to be loyal gatekeepers and spokespersons for science; and in return they enjoy high professional status and a self-identity associated with the scientific community (Aikenhead 2003, p. 38).

If Aikenhead's analysis is appropriate, science teachers expect the reward of a high professional status by teaching science as a structure or system of knowledge instead of teaching with a HPS approach that also conveys an image of science as practice and culture. Regarding the stable character of the scientific subject culture, HPS create challenges to science teachers' identities. A multiplicity of historical concepts, uncertainty of knowledge and evidences during the historical development of science, as well as the portrayal of science as being deeply rooted in culture and society raises feelings of uncertainty among science teachers. Moreover, only a few science teachers have got any formal education about the nature of their own discipline (Osborne et al. 2002). The vicious cycle is closed and reproduces the status quo of school science education.

The subject culture of physics manifests even in the design of rooms for teaching and learning (Willems 2007). Even though the quantity and quality of equipment and instruments for demonstrating physical phenomena varies radically according to national realities, rooms for physics teaching usually are characterized by a teacher-centered culture of teaching. Students' desks and chairs are usually fixed while the teacher's own space for demonstrating experiments and physical phenomena is demarcated clearly. Thus, the teacher's space is designed as a focal point of activities within the physics classroom. In this classroom set, a culture of discussion and negotiation is hardly supported.

Further evidence from psychological research enriches our understanding of physics teaching as a subject culture. In a study with 63 students of grade 11, the authors tested the implicit assumptions of students towards physics (Kessels et al. 2006). The study was aimed at describing the specific image of physics on the level of automatic associations. They found that students more easily associated physics (compared with English) with words referring to difficulty (than to ease), to males (than to females) and to heteronomy (than to self-realization). Furthermore, students generally revealed a relative negative implicit attitude towards physics and they associated physics more readily with others than with words referring to themselves. The image of physical science comprises difficulty, masculinity and heteronomy. A general reduction of students' positive attitudes is a consequence as several studies have indicated (Hoffman et al. 1998; Osborne 2003; Reid and Skryabina 2003). These aspects of the subject culture of physics contrast with an HPS approach claiming to have positive effects on girl's subject interests (Allchin 1997a; Heering 2000; Höttecke 2001) and which supports students' confidence in expressing their own ideas. The latter has been shown for instance by Henke et al. (2009) who focus on role-play and creative writing activities immersed in a larger didactical structure based on historical case studies.

In which respect is the subject culture of physics an obstacle to the endeavor of bringing HPS into the classroom? Table 1 provides an overview of the different and strongly contrasting positions.

Obviously, the ambitious didactical intentions related to HPS approaches sharply contrast with the above analysis of physics as being currently taught. Moreover, the subject culture has been indicated as being resistant to change. One can ask why should a teacher be willing to accomplish a radical break with a subject culture in which he/she was socialized into as winner of the system with the expectation of being rewarded by a high professional status? This question is concerned with the general problem of how to promote cultural change in educational systems. Notwithstanding research already has attended to teachers' systems of attitudes and beliefs, the problem of their change and development towards an increased acceptance and successful implementation of HPS as a teaching approach is rather unexplored.

Table 1 Culture of teaching physics necessary for implementing HPS compared to culture as it currently is

Effective history and philosophy in science teaching	The current culture of teaching physics
Physics is demonstrated as a process historically developed and influenced by a wider cultural and societal context	Physics is taught as truth and a collection of facts
Physics is demonstrated as a matter of empirical investigation, discourse, and negotiation among scientists that result in knowledge that has changed and may change in the future	Content is not a matter of negotiation and discourse among students
Students' conceptual development is supported. Processes of knowledge acquisition in science and in learning science are critically reflected	Teachers provide scientific content. Spaces are designed for enabling transmission of knowledge by teacher talk
HPS encourages students to express their own ideas	Students associate physics with heteronomy
Female role models are demonstrated	Physics is constructed as male

4 Attitudes, Beliefs and Skills of Physics Teachers

A common topic in the discussion of teacher education is their lack of knowledge about epistemology and history of science (Koulaidis and Ogborn 1989; Abell and Smith 1992; Aguirre et al. 1990; Lakin and Wellington 1994; Palmquist and Finley 1997; Irez 2006; Höttecke and Rieß 2007). An additional obstacle for implementing HPS in school science courses is the system of teachers' attitudes and beliefs. While we understand attitudes as affective constructs, beliefs are regarded as cognitive and emotional. Both constructs cannot be distinguished sharply. According to Pajares (1992) beliefs are descriptive ("I do teach mechanics"), evaluative ("I enjoy teaching mechanics"), or prescriptive ("I have to teach about forces at first and about inertia thereafter"). Educational beliefs are, like general beliefs, a broad construct. They encompass teacher's confidence in affecting students' performances, epistemological beliefs about causes and effects of teachers' and students' performance (e.g. motivation or anxiety), and about perceptions of teachers' selves like self-esteem, self-concept or self-efficacy (ibid., p. 316).

Attitudes and beliefs of science teachers regarding a new instructional behavior and its implementation are embedded in a socio-cultural context as in any other professional field. What makes teaching at school so special is the strong tendency of belief-systems to self stabilize. Pajares (1992, p. 323) claims that beliefs about teaching, learning and instruction may have survived nearly intact since teachers were students. They influence the motivation of teachers towards implementing new instructional behavior into their own field of practice (Jones and Carter 2007). Next to other factors, they also shape and influence the subject culture of teaching as described above. They are the result of the objectification of a subject culture on the level of the individual.

For the purposes of this paper, it is also relevant to understand what problems and benefits teachers expect from HPS for their own teaching. Teachers consider history of science as an additional didactic strategy, which complements other approaches and introduces new dimensions to school knowledge, but not as a content worth to be taught for its own sake. This and other findings were indicated in a study with Brazilian science teachers (Martins 2007) showing that they see teaching HPS content as an "extra" activity because it is not part of the mandatory curriculum, and something to be worked apart from regular classes. The negligible role of HPS has also been stressed during the national expert-meetings in the HIPST project mentioned above. Since time for covering all syllabus items usually is insufficient, teachers also regard the little time available as an impediment for introducing HPS in their classes (Martins 2007).

Learning about NoS usually is a major objective of HPS approaches. It is concerned with learning about process and context of science as well as with critical reflections on its conditions and constraints. However, research has indicated that teaching and learning about NoS is not an explicit objective of science teachers (Abd-El-Khalick et al. 1998; Lederman 1999; Mulhall and Gunstone 2008). Even if science teachers want to restrict their teaching objectives to the transmission of scientific content, they always and necessarily send messages about what science is, what matters in science or not, and how science proceeds. Although epistemological messages about the NoS during physics classes are unavoidable (Höttecke 2008), there is a lack of clear empirical research regarding how implicit messages about science and scientists actually influence students' epistemological understanding.

King (1991) has examined preservice teachers' beliefs about teaching and learning HPS. Even though she found in her study a majority of teachers appreciating an HPS approach, they had no clue how to teach it. Wang and Cox-Peterson (2002) presented further evidence about this problem. They found teachers' positive attitudes towards teaching history of science incongruent to their instructional practice. Therefore, a positive attitude of teachers towards an HPS based approach of teaching science counts at most as a necessary condition for teaching HPS. Wang and Marsh (2002) have examined elementary and secondary schoolteachers' use of history of science in their classrooms in more detail. As they have shown, teachers feel unsafe about how to use the history of science to demonstrate science as a process. On the other hand, they appreciate the benefits of this approach, but mainly for teaching science in a context. Obviously, teachers need further support for teaching specific scientific content, science as a process and NoS in general with an HPS approach. Indeed, Martins (2007) has found in a study based on a questionnaire with students and public schools teachers in Brazil that there is a lack of pedagogical knowledge regarding the didactic use of HPS as a means for teaching the NoS.

Furthermore, physics teachers' epistemological beliefs and their beliefs about teaching and learning are rather traditional (Tsai 2002; Markic et al. 2006). Physics and chemistry teachers are more receptive to the character of science as "standing pure and separate from all involvements in society" compared to biology and environmental science teachers (Witz and Hyunju 2009). Epistemological beliefs shape teacher's beliefs about teaching, learning and classroom management. The epistemological belief of science as a body of knowledge led teachers to favor instructional strategies provoking low-level understanding instead of deep conceptual understanding (Jones and Carter 2007). The idea of transmitting a body of knowledge to the students also hinders teachers to appreciate the role of the development of reasoning skills by their students. In summary, recent research about teachers' attitudes and beliefs systems has indicated its high degree of stability (Jones and Carter 2007; Yerrick et al. 1997). Such stability constitutes an obstacle for the implementation of HPS, because as long as new curricular and instructional practices related to HPS are in opposition to teachers' attitudes and beliefs, they will hardly accept them.

Therefore, besides attitudes and beliefs towards HPS, it is relevant to discuss the skills needed to conduct activities and classes that favor an adequate learning of NoS or concepts with an HPS approach. As we have seen, teachers usually feel quite unsafe about implementing HPS into their own instructional practice for several reasons. One of them is related to an attitude of uncertainty and a lack of confidence in positive outcomes, even for teachers who have a general positive attitude towards HPS in science teaching. Even if teachers do posses positive attitudes towards HPS it does not meant that they also posses an adequate understanding of it (Clough 2006). In addition, teaching about science with HPS is a quite demanding approach for science teachers. History of science does not offer clear-cut sets of scientific facts, evidence and concepts to be taught. Instead, teachers must conduct and mediate discussions among students about a multiplicity of them. Then, students have to be encouraged to express their different opinions, views and interpretations. However, as seen in the previous section, it is not part of the subject culture the majority of physics teachers belong to.

Bartholomew et al. (2004) have described five dimension of an effective practice for teaching ideas about science, which are also relevant for clarifying how demanding teaching about the NoS with HPS might be for teachers. Next to a proper epistemological understanding, they stressed the role of moderating open-ended dialogue in the classroom. The study indicated instead a strong tendency of the science teachers to control discussions and to close them down. The role of the students was restricted to answering questions put by the teacher before. Notwithstanding research has indicated strategies for reflecting the NoS explicitly and reflectively for learning about NoS effectively (e.g. Akerson et al. 2000), they are far from being a widespread practice among teachers.

Next to open-ended discussions in science teaching, narrative approaches have been widely discussed for teaching HPS, with significant and interesting results (e.g. Kubli 2005; Stinner 2006; Metz et al. 2007). A story about science for example has to be composed clearly, short and easy to remember (Kubli 2005). Story telling therefore is a method that demands sensitivity towards the audience and has to be prepared carefully (Klassen 2009). Independent of the didactical framework used, as large context problems (Stinner 2006), historical vignettes (Wandersee 1992), historical short stories (http://www.storybehindthescience.org) or case studies (e.g. Höttecke and Rieß 2009), it is of great importance that science teachers also have narrative techniques on their disposal in order to enhance the students' critical analysis of the content of the narrative presented to them.

Role-play is also a technique very often recommended for enacting and reflecting scientific process in the classroom (BouJaoude et al. 2003; Ødegaard 2003; Henke et al. 2009). In support of this method, students for instance re-enact controversies and negotiations among scientists and express their own ideas and interpretations of the social dimensions of science. However, role-play activities are not often used during science classes (Osborne et al. 2003) since science teachers usually lack essential teaching skills for guiding such activities.

Open-ended discussions, story telling, narratives and role-play are quite effective strategies for implementing HPS in science teaching. However, one should be aware that the skills demanded from teachers are closer related to the subject culture of teaching humanities than to the subject cultures of science. Thus, projects and initiatives for implementing HPS using such methods must also clearly provide those skills for teachers.

Table 2 summarizes and contrasts attitudes and beliefs of physics teachers currently found with those necessary for an effective implementation of HPS. There are additional insights about why it is difficult to bring HPS into the classroom are highlighted. Even if teachers learn about NoS, it is hard for them to transform their teaching practice for supporting students' learning about NoS. In addition, physics teachers tend not to value meta-scientific knowledge as teachable content. This is an important result, because if a teacher does not value learning about NoS as a central teaching goal, she or he disregards one major reason for supporting an HPS approach.

Table 2 Comparison of physics teachers' attitudes and beliefs necessary for teaching HPS to those empirically found

Effective history and philosophy in physics teaching	Attitudes and beliefs of physics teachers
Teachers have to focus on NoS as an explicit objective of their teaching	Teachers do not focus on NoS as an explicit objective of their teaching
Teachers know how to use HPS to transform NoS into teaching practice	Teachers do not transform NoS knowledge into a reflective teaching practice
Students reflect on the NoS explicitly	Students do not reflect on the NoS, teachers often convey incorrect messages about it implicitly
Teachers' beliefs about classroom organization are progressive. They acknowledge students' ideas and epistemological beliefs. They dispose of pedagogical content knowledge for moderating discussions and negotiations among students, support students' meaning making, and transform reflected views of NoS during their teaching	Teachers' beliefs about classroom organization, epistemological beliefs and beliefs about teaching objectives are likely to be traditional
Teachers appreciate learning content, context and process of science with HPS	If teachers appreciate history of science, they focus mainly on learning about context, but feel unsafe about teaching science as a process
Teachers have skills for teaching HPS like telling stories about science, moderating open-ended discussions and role-play	Teachers usually do not have skills for teaching HPS since valuing HPS does not belong to their subject culture

5 Institutional Framework of Teaching Science

Another obstacle considered for implementing HPS successfully is concerned with institutional boundaries set by curricular frameworks or assessment strategies for science education. The institutional framework comprises laws and regulations, organization of teaching and learning and the related infrastructure. Important factors fostering the inclusion or exclusion of HPS in science education are curricula and standards documents and their assessment. The situation in Germany and Brazil will be considered in the following example. Even though both countries differ in their developmental status regarding economy and education, they share another obstacle for an effective implementation of HPS.

Since 2004 standards for science education in Germany are in effect for all of the 16 German states. This standards document is based on a description of learning outcomes and goals in terms of students' competencies. Four major areas of competencies are described: subject knowledge, epistemological knowledge including typical methods of the subject, communication and judgment.

Within the physics standards document the role of history of science for the benefit of general education is pointed out clearly. Physics has to contribute to general education as it enables the pupils

> […] to understand the language and history of sciences, to communicate their results and to get to know discovery methods of knowledge and their limits
> (Joint Board of Ministries for Culture and Education of German Federal States 2005, p. 6).

If we analyze the standards document as a whole, we encounter an important problem regarding the role of history of science. First, even though the role of history for reaching scientific literacy was highlighted, history is not mentioned again in the document besides for the description of the competence of judgment. The standards document expresses the high relevance of history of science, however, history seems dispensable for the development of competencies. History is just a label for a high-level goal of science education. Moreover, the German standards for science education restrict the role of history to a demonstration of the effects of science in historical and social contexts (standard B4).

This kind of problem also appears in Brazilian standards documents for basic education. Brazil, like other countries in Latin American, is committed to promote educational reforms aiming at overcoming its significant educational deficit. The Ministry of Education has organized the Secondary Education Reform Project in 2000 as part of a broader social development policy that attaches priority to actions in the field of education. One of the tasks of this reform was to set up the National Curricular Parameters (PCN), which, among other issues, emphasizes social and cultural contextualization as necessary. In the case of physics (as in other subjects), such a contextualization is expressed as a list of recommendations: recognizing physics as a human construction; teaching aspects of its history and its relationship with cultural, social, political and economic context; recognizing the role of physics in the production system, and understanding the evolution of technology and its dynamic relationship with the evolution of scientific knowledge (Brasil 2002, p. 32).

Thus, German and Brazilian standards documents reveal a problem we already have spotted with physics teachers: there is no clear idea expressed that the history of science also matters for teaching and learning scientific content as well as for science as a process. Such a clear idea, for instance, could have been communicated with concrete examples of tasks and activities for students. It seems that the problems with implementing history of science faced by physics teachers are also rooted in these documents. Despite the official role of history of science as an overall objective of science teaching, the operationalization into concrete descriptions of competencies and how to develop them are not sufficiently demonstrated in either document. Hence, for fostering HPS in the classrooms it is necessary to demonstrate that HPS matters on all curricular levels without being restricted to a level of general objectives. Detailed descriptions of expected learning outcomes should therefore integrate the concrete role of HPS in fostering competencies including knowledge of scientific content.

Teachers usually are guided strongly by curricula, if they have the character of to-do lists. Thus, curricula contain the hidden message that teachers can ignore all goals that are not sufficiently exposed. This is actually the case for HPS. But for supporting teachers to teach HPS in their classrooms they have to be encouraged and guided by standards and curricula to teach with and about HPS. The values embodied in curricula and standards documents have to be transformed for assisting and guiding teachers to adopt a more positive approach to teaching HPS.

Table 3 summarizes and contrasts the current state of the institutional framework regarding the implementation of HPS and its necessary development.

The discussion above indicates that even if curricula and standards documents support HPS on a general level they are in danger of conveying hidden messages that HPS can be ignored. The development of assessment strategies in Germany is still an ongoing process, but as far as we know, HPS will do not play any explicit role. As long as the role of HPS is restricted to a general level of objectives without being outlined in detail and clearly indicated as relevant for learning scientific content, science teachers hardly will regard them as important for their actual classroom curricula.

Table 3 Comparison of necessary development of curricula and standards documents to their current state

Aspects of a desirable institutional framework supporting HPS	Current institutional framework for science teaching
Teaching and learning about HPS is an overall objective. Descriptions of competencies are related to HPS	History is an overall objective, but suffers from an operationalization towards strategies of effective implementation
Teachers are encouraged and guided by standards documents to teach with and about HPS	Teachers are strongly guided by the to-do lists of curricula which rarely include teaching the HPS
Curricula contain the explicit message to teach HPS in order to enhance competencies in science	Curricula contain the hidden message to ignore HPS

6 HPS in Textbooks

There are several papers discussing the relevance of curricular changes and teacher training programs in promoting the implementation of HPS in classrooms (e.g. Monk and Osborne 1997; Adúriz-Bravo et al. 2002). However, textbooks are scarcely addressed as key elements in this process. Despite all new technologies and resources, textbooks still play a crucial role in science education, since they are important tools for relating the scientific content taught, teachers and students and their understanding. Usually, in school science, the textbooks are the main source of knowledge, provide the majority of instructional material and activities and strongly influence curricular decisions. In addition, textbooks count as one of the most reliable source of knowledge for students and teachers. For those teachers, who do not attend vocational training course, textbooks serve as the most important means for communicating curricular innovations to them and are a source for their own professional development.

The historical and philosophical content and consequent views on the NoS conveyed by textbooks are likely to shape teaching science. Historical-philosophical aspects contribute to promote contextual science teaching, however, their absence or even their misrepresentation generates distorted views on the NoS. Some historical narratives nourish common views about the NoS based on empirical-inductive conceptions and convey the idea that science is constituted of irrefutable truths produced by geniuses (Allchin 2004; Martins 2006). The vast majority of textbooks include some historical content reduced in the form of dates, names and timelines. Approaches like that have a strong whiggish influence and there are many more pseudo-historical narratives than transpositions of good historical studies. Such demonstrations of science reinforce the popular scientific myths spread on students and teachers' imaginaries. In addition, they explicitly transmit common misconceptions about the NoS (Pagliarini and Silva 2007; Abd-El-Khalick et al. 2008; Irez 2008).

Indeed, the effect of including history of science in science education depends mostly on which history of science is used and how it is used. Usually teachers lack initial education on history and philosophy of science. Therefore, their own professional development and teaching practice in this field heavily depend on accounts of science conveyed in their textbooks. Hence, teachers will rely on how science is portrayed, which history of science is considered and which views on the NoS are conveyed in the textbooks in use (Leite 2002).

Scholarly criticisms about the HPS taught at schools are not difficult to find. Usually teacher beliefs and scholar beliefs about what a proper HPS and NoS teaching should be differ radically because what counts as adequate material, textbook, experiment, case studies, etc. from a historian of science's viewpoint is different from a science teachers'

Table 4 Comparison of desirable HPS content of textbooks and the current state

Desirable demonstration of HPS in textbooks	HPS currently conveyed by textbooks
Historical accounts that foster adequate views on NoS and portrays science as a social enterprise	Historical narratives that reinforce the naive empirical inductive view of science. Social and cultural influences are rarely discussed
Textbook content suitable for students and teachers' learning about HPS	Historical information resumes to dates, names and timelines
Historical content combined and integrated to scientific content	Historical content isolated in boxes that are dispensable for the learning of scientific content
Activities that foster explicit reflections on NoS	Notions about NoS are conveyed implicitly; activities addressing learning about the NoS are absent
Collaborative work of historians, philosophers and textbook writers	Historians and philosophers are not involved in textbooks writing

perspective. The gap between professional cultures is not essentially problematic since teachers are not historians of science, historians of science are not schoolteachers, and both do not have to do the job of the others. The gap is unavoidable,[2] because the expertise necessary for doing a good job in each field is very different and each side has different goals, different everyday work, and faces different tasks and problems. However, it has to be stressed that many scholars already have contributed substantially to provide a wide range of materials and strategies for teaching and learning science with HPS (e.g. Allchin 1997b; Barth 2000; Heering 2000; Höttecke 2000; de Berg 2005; Howe and Rudge 2005; Stinner 2006; Metz et al. 2007; Quintanilla 2007; McComas 2008; Forato 2009; García 2009; Henke et al. 2009).

From the academic viewpoint, textbook knowledge is fragmented, since textbook writers choose and include just a few aspects of a broader field of knowledge. Usually, the historical content is presented in boxes detached from those parts of the text where the scientific content is presented. In these boxes, isolated events, dates, names and timelines are demonstrated as historical "facts". In most of the cases an anecdotal narrative style is preferred. In addition, historians of science and philosophers are hardly ever consulted in the curricula development process or by textbooks authors, who usually are teachers.

As we have seen above, teachers have epistemological beliefs and beliefs about teaching and learning that guide and shape their interpretation and use of textbooks. Osborne et al. (2003) stress the role of textbooks for implementing curricular innovations as a vital resource that supports teaching. In the case of implementing HPS, they play an even more important role because they must convey historical and philosophical content as well as activities and methods that help to overcome the current subject culture of teaching physics. In addition, teachers tend to ignore innovative content they are not familiar with and that requires special teaching skills they do not possess. Considering the relevance of textbooks as an important source for teachers' own learning about HPS and NoS, distorted demonstrations of science in textbooks are even more alarming. Textbooks hardly offer any learning opportunities to explicitly confront teachers' and students' views with more elaborated ideas on how science proceeds (Table 4).

[2] The gap is unavoidable but not unsolvable, as illustrated by projects carried on in different continents addressing HPS in a fashion that science teachers, science teacher educators, and historians of science find valuable. For instance, see HIPST project carried on in Europe (http://hipst.eled.auth.gr); Resource Center for science teachers using Sociology, History and Philosophy of Science (http://www1.umn.edu/ships/), The Story Behind the Science (http://www.storybehindthescience.org) carried on in United States.

7 Perspectives on Successful Implementation Strategies for HPS in Physics Education

We have started with a discussion of unsuccessful HPS implementation in physics education. Four central obstacles for an effective teaching with HPS approaches were analyzed and put into perspective. In this section, we discuss aspects that implementation strategies should take into account in order to overcome these obstacles. They are based on the idea that curricular innovations like HPS have to be transferred from a context of development to a wider context of adaption and application. Transfer therefore is one aspect of implementing a curricular innovation next to its development and wider dissemination. For fostering transfer of a curricular innovation, it is necessary to consider the context of adaption and application as a social system. Gräsel et al. (2006) point out that complex social systems like the educational system have a strong tendency to immunize themselves against change and innovation. They construct their own cognitive structures, patterns of expectations and identities that operate as filters and defense mechanisms against external interventions (ibid., p. 456f). The same holds for the culture of teaching physics as a subsystem of the educational system. If we consider the terms and conditions of successful implementation of HPS, it is not sufficient to expect teachers to be the single agents of innovation. We have to admit that educational systems as a whole have to be developed and considered as a social and a learning system. Thus, there are additional agents necessary for a successful implementation of a curricular innovation like HPS that must be considered (Abel 2006; Gräsel and Parchmann 2004; Gräsel et al. 2006; Reinmann-Rothmeier and Mandl 1998; Snyder et al. 1992):

- Groups of teachers working collaboratively and supporting each other while adapting HPS ideas and materials to their local conditions
- School principals who support the innovation by intellectual stimulation and the support of innovative visions
- Experts supporting teachers on several levels as adapting or even developing new instructional ideas and materials and working symbiotically, where different kinds of expertise (research and practice) are involved
- School administrations supporting an innovation like HPS-oriented teaching and learning physics with adequate standard documents, curricula and regulations addressing and supporting HPS explicitly

In the following paragraphs, we suggest and discuss means and conditions of a system control, which according to our view, are proper means for overcoming the obstacles discussed in the first part of this paper. The perspectives we will develop take the systemic character of educational systems into account and address all agents of change, not only single teachers. We focus subject cultures and their development as well as the role of standard documents and curricula. We suggest the development of support structures enabling teachers to teach HPS successfully. Finally, we briefly highlight the roles of teachers' professional development and written resources; and perspectives for future research and development aiming at overcoming the obstacles. We do not presume that it is neither possible nor even desirable that all factors of system control we subsequently discuss have to be changed or improved at once.

7.1 Subject Cultures, Their Development and Their Contribution to HPS Implementation

We have discussed the role of subject culture of teaching science in general and physics in particular. The subject culture emerged as one of the most stabile factors generally preventing science education from change. Subject cultures are, as any other culture, based on the interactions of its supporters. As has been mentioned above, they comprise the entirety of processes, methods, instructional strategies, content to be taught, as well as expectations, accepted habits and curriculum emphases of its members. They are hardly changeable with single efforts. Instead, a change of a subject culture can be enabled only slowly and gradually by different kinds of activities like teacher education, vocational training, development of curricula and standards for science education as well as the development of resources for teaching and learning, like textbooks.

A subject culture, which supports the implementation of HPS, should comprise teaching science as content, process and culture at the same time is somehow self-evident. This would include the image of science as a human endeavor and a shift from a traditional teaching paradigm (transmission of content) towards teaching as an activity supportive for learning (facilitating of learning). Single efforts for changing a subject culture as a whole will hardly effect any substantial change. While subject cultures behave like huge networks, efforts towards changing them are nothing more but slight irritations of the network.

7.2 Standard Documents and Curricula

The inclusion of HPS in standards documents and curricula should be emphasized stronger and more explicit. Only a few standard documents like the Project 2061 (AAAS (American Association for the Advancement of Science) 1990) do stress the role of HPS for teaching science in a satisfactory way, as far as we know. Curricular and standards are instruments for moderating educational systems as they determine educational goals, proper activities and content to be taught. They are the part of the educational system that can be influenced from the outside more directly for example via policy-makers. Standards and curricula should support teachers by concrete curricular ideas, suggestions for student-centered activities or best-practice-examples embedded in such documents which guide their every-day teaching with suggestions of methods, media and content.

As has been shown, the inclusion of HPS on a rather general level of objectives is even in danger to convey to teachers the hidden recommendation to ignore HPS. As long as general curricular objectives related to HPS are not broken down to the level of enacted curricula, they will neither influence science education substantially nor target the level of learning objectives concerned with HPS. If HPS is indicated as supporting scientific literacy for instance, examples should briefly highlight how such a high-level goal can be broken down to concrete actions of the teacher and activities of students. We consider the level of learning objectives defined by standard and curricular documents related to HPS as an important means to stimulate implementation. As learning objectives, we consider the development of epistemological as well as conceptual understanding, skills of problem solving and knowledge acquisition, historical awareness, positive attitudes towards and interest in science and the development of metacognitive skills.

7.3 Support Structure on the Levels of School and the Institutional Framework of Teaching

Setting up support structures generally facilitates the implementation of curricular innovations. They are located on an institutional as well as on a local level (schools). Reinmann-Rothmeier and Mandl (1998), in their general analysis of why implementation of curricular innovations often fails, are acquainted for the importance of such supportive structures:

> The implementation of new curricular concepts or media stands and falls with the cooperation of people involved. Even though the commitment of single persons is highly desirable it is doomed to failure, if no support from the inside or outside will be available (translation our own, pp. 309f).

Support structures are obviously needed. Policy makers, school administrations, research institutes, teacher training programs or centers for professional development usually maintain support structures (from the outside). On a local level of support structure teachers collaborate on school level (the inside) in order to develop ideas and materials, encourage and advise each other, and share strategies, expertise and experiences. This kind of supportive infrastructure has been indicated as a central feature of successful implementation (Gräsel and Parchmann 2004; Stadler et al. 2007). Thus, a climate of cooperation and collaboration, regular meetings for evaluating and discussing the status and achievements of implementation of HPS are important factors of success on a local level. The principles of schools can support teachers by supporting their ideas, by intellectual stimuli like contact to scientists or research institution (Gräsel and Parchmann 2004) and by providing additional resources supporting a collaborative infrastructure on a local level (time, money, spaces, removal of other loads like reduction of teaching duties).

An alternative support structure, which aims at merging the "outside" and "inside", is provided by the model of participative action research projects (Eilks et al. 2004) which recently has been adapted to foster implementation of HPS (Höttecke and Rieß 2009). According to this approach, researchers and teachers both contribute with their special expertise and perspectives to a developmental process of HPS-based materials for teaching and learning. According to this model, teaching sequences are developed, evaluated and reworked in cycles. In the end of the process, resources for teaching and learning are developed which are highly adapted to the professional field of teachers. Teachers' content knowledge about HPS and their pedagogical content knowledge (how to teach specific HPS issues and how to address NoS aspects) are reflected and developed during a developmental process. Researchers contribute with their expertise about teaching and learning and with their knowledge about HPS. The model counts as effective for teachers' professional development. However, the problem of a broad implementation is still not satisfactorily solved, since the number of teachers participating is rather restricted.

It is also necessary to provide support for teaching science in general and physics in particular with HPS regarding local infrastructure and resources. Devices for demonstrating experiments or inquiry learning within an HPS approach usually differ from those needed for traditional ways of teaching science. For instance, it has been stressed that redoing experiments with replicas of historical instruments can enhance an HPS approach of science teaching (Heering 2000; Höttecke 2000; Henke, Höttecke and Rieß 2009). Their augmented availability is another aspect of a local support structure.

7.4 Teacher and Process of Teaching

The most important factor for implementing HPS is the science teacher. Next to his or her own adequate epistemological understanding and knowledge about HPS a dialogic orientation towards teaching science, tolerance and skills to moderate open-ended discussions, narrative skills and a general attitudes toward science teaching as a process of meaning making have been outlined as central aspects. Teacher education and professional development are of great importance since curricular innovations as HPS usually fall through stable systems of beliefs of teachers about teaching, learning or epistemology

(Gräsel and Parchmann 2004). Short-term activities generally are unlikely to be successful in provoking long-lasting effects regarding the professional development of teachers since results are limited to "honeymoon-effects" (Lindner 2008). Indeed, it is not rare that teachers who have visited a short-term vocational training often feel encouraged or even enthusiastic to teach a new curricular idea the training was about, but the enthusiasm and positive attitudes induced by the training usually do not have any long-lasting effects. Instead, teachers would deliberately implement HPS into their own professional field, if they will have made positive and adequate experiences with HPS during their own education and in-service training courses. This aspect is relevant for teacher trainers, who want to foster HPS. Next to conveying knowledge about HPS and NoS they have to teach how they preach. This means that teacher training courses should be dialogic, enable open-ended discussions, foster narrative skills and enable students' meaning making about science in a reflective manner.

7.5 Written Resources

Due to the hitherto mentioned factors, the development of HPS oriented resources becomes more important. Considering that we neither expect teachers nor students in school courses to be or become experts in history of science, we should work on some standards enabling well-founded decisions on which historical content should be included in curricula and textbooks and on which level of elaboration. In addition, such criteria are not univocal, they strongly depend on social and pedagogical school realities, national standards as a whole and on the target group a textbook addresses (e.g. teacher trainers, teachers own learning, students at school).

Instructional materials ought to satisfy several demands in order to be suitable: they have to meet the high quality standards of research about history of science and NoS (avoiding whiggish approaches, being historically accurate, demonstrating science as tentative, being based on evidence and inference, being embedded in culture and society, being a social enterprise, stressing the role of negotiation and controversy among scientists, …). At same time, they simply have to be acceptable for science teachers as they are. Here we do not mean those teachers who are already well informed about HPS and meet the high standards of professional development mentioned above. Instead, we mean physics teachers, as they currently are, being part and product of the subject cultures, in spite of the fact their orientations are likely to be rather traditional and hardly directed to the goals endorsed by HPS proponents. Written resources therefore have to answer to what science teachers usually are asking for. Even though strongly NoS-oriented materials might be highly desirable for several reasons, it is unlikely that average physics teachers will make extended use of them. The transfer of innovative instructional materials from a context of development to a context of application has to be understood as an open process where teachers are involved as a final step (Abel 2006). Teachers should feel like benefiting from the new materials, they should meet their norms and experiences whenever possible and materials should be flexibly designed in order to allow teachers to adapt them to their current and local conditions (Gräsel et al. 2006).

Furthermore, historical case studies or narratives very often are too extensive in order to be implemented into current tight science teachers' schedules. Are they too demanding? From an academic perspective certainly not, but from a teachers' perspective they often are. As long as teaching science or physics respectively is an activity performed under high-pressure (stuffed curricular, preparation of students for central assessments, etc.)

research and development activities have to make compromises. As long as teachers hold the key position towards a successful implementation of HPS in physics teaching, teachers' perspectives, beliefs, attitudes and major fields of duty have to be taken into account while developing written resources.

In order to respect the subject culture of teaching physics, it is necessary that HPS content be concretely part of school curriculum, not as vague items as they usually appear. Otherwise teachers and students will tend to ignore them as an add-on. It is positively relevant that examples, case studies, narratives, vignettes, and other kinds of text brought in textbooks are closely related to the scientific content to be taught, at the same time it fosters scientific literacy or knowledge and beliefs about NoS. It is also indispensable that complex and subtle ideas such as NoS tenets are addressed explicitly in textbooks, with clearly formulated learning activities.

It is desirable to research about which scientific content is appropriate to be taught with history and which is not, keeping in mind that a combination of learning about scientific content, history and the NoS is crucial. Moreover, it is almost a pre-condition that textbook writers work collaboratively with scholars and teachers in order to assure proper HPS content that fits to teachers' needs.

7.6 Research and Development

Research and development can support implementation of HPS either by developing and evaluating research-based materials, which must be highly adapted to teachers' professional fields, or by supporting this process with further research evidence. Research is still needed for clarifying the effects of different HPS oriented learning environments and their influence on central personal variables like self-realization, interest or motivation, emotional experience as well as cognitive and meta-cognitive skills. We have stressed that teachers do have a key position for implementing HPS in school science. Thus, their perspectives, doubts, fantasies, fears and perceived demands on teaching and learning with HPS also ought to be studied more in detail.

Even though research has already indicated positive effects of HPS on learning science on several levels as discussed in this paper, the role of teachers' professional development, their pedagogical content knowledge related to HPS, and the necessary support structures for teaching science has not been sufficiently explored in a systematic way yet. Regarding the role of written resources for enabling teachers to teach science with HPS researchers have not fully understood how science or physics teachers without any extend education in HPS do interpret and use these materials.

Implementation strategies can be more effectively adapted to the practice of science teachers in general and especially to the subject culture of teaching physics, if the transformation of curricular ideas guiding the development of these resources from the context of development to the context of transfer and dissemination will be better understood.

8 Concluding Remarks

This paper was guided by the idea to contribute to an improvement of the status of implementation of HPS in science education in general and in physics education in particular. We followed a two-step approach. First, we analyzed obstacles for implementation identifying aspects of the subject culture of teaching physics, skills attitudes and beliefs of physics teachers, which constitute obstacles related to the institutional framework of physics education at school. We also analyzed problematic representations of HPS and NoS in textbooks. In the second part of the paper, we discussed some aspects that should be taken into account by future projects enforcing implementation of HPS. There we have focused the character of educational systems as social networks and derived the necessity of the development of collaborative structures and actions for supporting and encouraging teachers to follow a HPS approach willingly and successfully. We also mentioned and discussed several further aspects of a supportive structure including curricular development, school administration, written resources, and research and development. The status of implementation finally can be improved on several levels. Single projects will unlikely be able to contribute to an improvement of all aspects at the same time. Instead, continuous actions are needed on several levels in order to improve the situation during the course of time. The social realities of teachers, their capacities and the subject cultures they are immersed into should be taken into account in any case.

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