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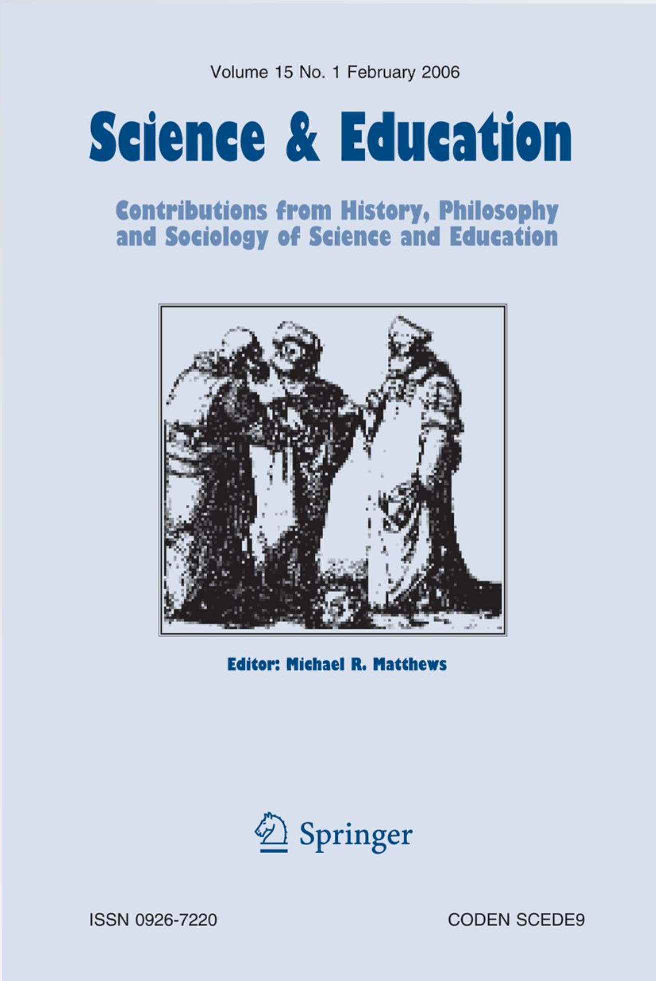

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Implementing History and Philosophy in Science Teaching: Strategies, Methods, Results and Experiences from the European HIPST Project

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Abstract This paper presents a rationale for utilizing HPS to teach physics and the NoS developed in the course of a project funded by the European Union. A core feature of this approach is formed by the development of historical case studies for the use in lessons. Furthermore, the learners' perspectives are explicitly taken into account. Teaching methods comprise student-centered activities as creative writing for understanding science and scientists and role-play activities. Emphasis is laid on experimental work which is performed with the help of true-to-the-original replications of historical apparatus, especially built for this purpose. A new characteristic for NoS learning is introduced, namely the reflection corner giving the opportunity to explicitly discussing the relationship between history, knowledge acquisition, and the application of scientific findings. In order to make use of the special skills, creative potentials and experiences of teachers a symbiotic strategy for the development and evaluation process of the teaching material was adopted where a close and long-standing cooperation between science teachers and science educators could be established. On this basis the German partners were able to complete numerous case studies from the fields of mechanics, electricity, magnetism and heat.

1 Introduction

Science educators and researchers have argued for the implementation of history and philosophy of science (HPS) in science teaching (e.g. Matthews 1994) for a long time.

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Although various benefits for teaching and learning science and about science have been pointed out, the status of its implementation is rather deficient (Höttecke and Silva 2010; Monk and Osborne 1997). Focusing on physics education Höttecke and Silva (2010) pointed out four major obstacles that prevent successful implementation of history and philosophy of science in formal education:

- Characteristics of a culture of teaching physics which differs from other school subjects, physics teachers are more likely to be content-driven, and follow traditional general beliefs about teaching and learning;
- A lack of professional skills to teach about nature of science (NoS) and HPS, traditional beliefs about teaching physics along with inadequate epistemological beliefs;
- A lack of support from the institutional framework of science teaching (curriculum development);
- A lack of adequate HPS content in textbooks.

Overcoming such obstacles is obviously a long and demanding process not manageable by any single project. Nevertheless, projects targeting the development and implementation of HPS may have at least a limited impact. HIPST (History and Philosophy in Science Teaching, 2008–2010) is a European project focusing on more effective strategies of development and implementation of HPS into science teaching. The obstacles mentioned above have been taken into account as far as possible. There are 10 partners from 8 European countries (Germany, Greece, Hungary, Israel, Italy, Poland, Portugal, UK). A detailed account on guiding ideas, objectives, framework, and management structures of HIPST has been described elsewhere (Höttecke and Rieß 2009).

The project specifically aims at the development of teaching and learning material for learning scientific content as well as learning about epistemology, processes and contexts of science. Science teachers are systematically integrated into the developmental work to enhance their attitudes, beliefs, competences and general professional skills. Therefore, operationalizing high level objectives for learning with and about HPS as well as the NoS is a central topic of this project.

Partners collaborate in order to achieve the following general aims of the project:

- Increase the inclusion of HPS in science teaching for the benefit of scientific literacy.
- Improving strategies for the development and implementation of domain-relevant materials, teaching and learning strategies into educational practice.
- Strengthen the cooperation, establish a permanent infrastructure and build a sustainable network of relevant stakeholders in the field of scientific literacy and public understanding of science (schools, museums, universities).

A major goal of the project was to increase the availability of HPS related teaching and learning material all over Europe and abroad. Therefore, numerous case studies for teaching and learning science with HPS were translated into English. In a second step, several of them were translated into the national languages of the participating countries. All case studies were collected in a wiki-space allowing access to and integration of different kinds of media like presentations or film. The wiki-space serves as a platform for allowing public access to the case studies.[1] This way, the project raises the availability of thoroughly developed and evaluated case studies on how to teach and learn science as well as about the NoS, as researchers have asked for (e.g. Akerson and Abd-El-Khalick 2003; Bartholomew et al. 2004; Höttecke and Silva 2010).

[1] http://hipstwiki.wetpaint.com/.

This paper gives a summary of strategies, methods and results the German HIPST groups have developed collaboratively in order to contribute to compensating for a poor status of implementation of HPS in science teaching (Höttecke and Silva 2010; Monk and Osborne 1997).

This paper explains the methodological framework of our work. We explain why we have focused on the development of case studies and how we understand this format of presenting scientific content together with the HPS and the NoS. The consequent consideration of learners' perspectives is another fundament. Methods for teaching and learning within an HPS approach like student-centered activities, creative writing, role-play, and experimenting with replicas of scientific instruments of the past will be explicated. Several examples borrowed from our case studies illustrate how we understand and use such methods. Next to a series of case studies for teaching and learning we developed a method for explicitly and reflectively addressing the NoS. It will be outlined as well. Our development model follows a symbiotic approach of collaboration of experts from different fields namely science teachers and researchers from Universities. The general model and the structures of the development process will be explained. A final discussion summarizes the major achievements of the project including a discussion of general insights in a project like HIPST.

2 Development of Case Studies

The concept of teaching and learning with case studies considers science in a detailed, but exemplary manner in order to highlight general aspects of science, epistemology, scientific content and the NoS. Regarding the field of NoS some scholars have established a kind of "consensus view" of the nature of science which comprises a set of aspects widely accepted in standard documents and philosophy of science.[2] On the other hand such a consensus view is hardly accepted among science educators.[3] Instead of a definite set of characteristics the NoS appears to be more of a heuristic for expanding teachers' and students' attention from the limited view on content and products of science to a broad scope including professional scientific activities and the context in which they are performed. Or to put it in Hans Reichenbach's terms (1938), the focus of teaching shifts from the context of justification to both, the context of justification AND the context of discovery.

According to our understanding the narrative character of a case study is one of its prominent features. It should exemplify a confined setting and have a clear beginning and end. General characteristics of science are highlighted, for example the empirical and inferential NoS, the role of instruments, experiments, theories, models or specific skills of scientist and their helpers. Furthermore, showing the interrelation of society, culture and science is central. Science should be portrayed as a human and social endeavor; the portrayal must include perspectives on motivations of scientists, on conflicts, controversies and blind alleys. The role of trustworthiness, credibility and expertise, creativity and communication in establishing new knowledge, methods, instruments or material procedures are other important issues which can be exemplified in authentic contexts. We regard science "in the making" not as a linear process, characterized by the false dichotomy of

[2] Abd-El-Khalick and Lederman (2000), Lederman (1992, 2007), McComas et al. (1998).

[3] Eflin et al. (1999), Irzik and Nola (2010), Osborne et al. (2003), Niaz (2001), Smith and Scharmann (1999).

success or failure, but as an endeavor characterized by its detours and mistakes balanced by creative solutions and a self-correcting nature. Such a broad scope on science can be realized within a narrative approach focusing on a storyline along one central idea (Stinner et al. 2003).

Furthermore, the concept of case study stresses the active role of the learner, indicated by the expression "study". It is obvious, that general aspects of learning and motivation like conceptual change, students' epistemological beliefs, their interests and general attitudes towards science and science learning (Hodge 2006; Hoffman et al. 1998; Osborne and Collins 2001; Osborne 2003) have to be taken into account while designing case studies.

3 Considering Learners' Perspectives

There is large evidence for positive effects of HPS on students' interests in science and their understanding of the NoS.[4] On the other hand, activities like experimenting, making observations and discussing prove to be promising instructional strategies on the basis of research results about students' interests. Low potentials for fostering students' interest in science have been indicated for activities like listening to talks and reading texts (for an overview see Merzyn 2008). But still, even discussions among students after having read historical vignettes about past science "can easily become a passive experience" (Rudge and Howe 2009: 565). Rudge and Howe warn that excessive attention to historical details may even be perceived as extraneous by the students.

For an HPS approach to science teaching this is obviously a challenge. Historical narratives including vignettes and the like are often presented by teachers by means of presentations, talks or more or less extended lectures. The HIPST approach therefore focuses explicitly on the development of student-centered activities like experimenting, making observations, discussing, and role-play. By doing so, a variety of creative and open-ended methods of teaching and learning science have been established. Fostering these activities will develop the culture of physics teaching in general (Höttecke and Silva 2010) and shake the dominant position of teacher-centered activities in science lessons. Matching the students' apparent interest in discussions, opportunities for discussing and negotiating ideas have to be realized in the classroom together with procedures of generating and evaluating scientific evidence among the students.

But, how should historical concepts of science best be related to the modern textbook view on scientific knowledge? Monk and Osborne (1997) have suggested a model which is consistently based on a constructivist perspective on learning: The teacher presents a phenomenon and encourages the students to present their own ideas and explanations. After the introduction of historical ideas and concepts they are validated experimentally. In the end, the respective textbook content is presented. Further experimenting and a final discussion complete the unit. Monk and Osborne state that the "teacher's exposition [of the textbook perspective] is by now, one more voice offering one more viewpoint, rather than a singular, unquestioned view" (ibd., 419).

The idea Monk and Osborne have developed is tempting, but it does not sound realistic. The problem of relating historical and modern scientific thinking and knowledge to each

[4] Abd-El-Khalick and Lederman (2000), Galili and Hazan (2001), Howe and Rudge (2005), Irwin (2000), Lin and Chen (2002), Lin et al. (2002), Kubli (1999), Mamlok-Naaman et al. (2005), Olson et al. (2005), Rudge and Howe (2009), Solbes and Traver (2003), Solomon et al. (1992).

other within an HPS-based teaching approach is not yet solved. Instead, students' experience with the teachers' and textbooks' authority on presenting final-form science (Duschl 1990) makes it seem highly plausible, that they will regard the textbook knowledge as *the* superior scientific view and that attempts to understand the history of science are regarded "as simply a waste of time" (Rudge and Howe 2009: 565). However, Monk and Osborne have stressed that teachers should avoid a characterization of the modern scientific view as the only correct one and that a more instrumental view of modern knowledge should be communicated to students.

Considering this problem seriously it is hard to believe that the approach proposed by Monk and Osborne can work as intended. Students as well as physics teachers are immersed in a subject culture of teaching and learning (Höttecke and Silva 2010) which is quite traditional and emphasizes the security and completeness of current scientific knowledge. Although Monk's and Osborne's general ideas about conceptual development are close to ours we doubt that such a strong focus on *knowledge* will be helpful. Extensive training of science teachers will be needed in order to enhance their individual conceptual viewpoint towards an understanding of science as a *discourse* and a means of *knowledge production*. We should take into account that HPS appears to be a rather unusual approach for most of the science teachers and their students. Teachers usually are lacking adequate skills to teach about a multiplicity of scientific concepts instead of one single truth. We suggest two helpful perspectives on the use of HPS in science teaching:

(a) If a teacher decides in favor to follow an HPS approach of teaching he or she should clearly justify the approach to his or her students. A message like the following might be helpful: The study of knowledge from past science concerns knowledge that scientists once held to be valid, useful and appropriate and nevertheless was criticized over the course of time. Therefore, knowledge from past science and its historical development can guide our understanding of current scientific knowledge and the rationales for believing current knowledge to be valid, useful and appropriate. We do not regard historical developments to lead to our current understanding in any linear manner, but the question of which knowledge might simply be true or superior (and from the students' perspective usually the modern view will be regarded as such) will shift to the question of how the community of learners in the class room will learn. The focus on the historical development should be justified with an argument concerning the process of learning. HPS is demonstrated as a strategy of learning science.
(b) The students should know that as long as they learn science in a historical context, the focus of teaching and learning will be shifted from knowledge acquisition to understanding the processes of doing science. Our own experience with students indicates the attractiveness of such a perspective and its power to convince students on university as well as on school level. Detailed empirical research results about this issue are still lacking as far as we know.

Both suggestions deal with the problem that students as well as their teachers usually are acquainted with quite traditional patterns of teaching science stressing the role of knowledge acquisition (instead of learning about processes), focusing scientific content (instead of the development of such content) and assembling merely a systematic structure of knowledge (instead of historically grown structures). Thus, if we design models for teaching and learning science with HPS we should take into account the expectations of students that science usually is taught as a collection of "true" knowledge. After some years having been taught science in traditional manners students will not easily switch to an alternative and historical perspective on science and scientific knowledge. Even if a science teacher rigorously rejects the idea of correct knowledge in favor of an instrumental perspective on science, like Monk and Osborne (1997) have recommended, it is unlikely that his or her students just follow and accept this rather new perspective without any resistance. Before students will appreciate the role of historical concepts and knowledge for their own learning and even more so before they accept the idea that learning about HPS is not "a waste of time", they have to make as many fruitful experiences as possible with the inspiring nature of history and philosophy of science for the development of their own thinking and learning. This is a major reason for the development of student-centered activities for teaching and learning with HPS as outlined below.

Our approach shares this strong consideration of students' perspective with the model of educational reconstruction (Duit et al. 2005). The model aims at balancing science oriented and educationally oriented issues for the benefit of instructional models enabling conceptual change. At first students' interests, prior ideas and beliefs about a certain scientific content to be learned (e.g. mechanics) need to be explored. At the same time this science content itself will be classified, analyzed and structured. The design of a learning environment and an instructional model is finally based on the thorough consideration and relation of both of these aspects. Thus, an instructional model we are aiming at is far from being merely a reduction of neither any scientific content nor any content from the history or philosophy of science. An exhaustive and purposeful reconstruction under an educational perspective is intended instead.

Teaching and learning science with HPS, which aims at a better understanding of the NoS, introduces another level of complexity. Both major aspects of the model have to be extended to cover ideas and beliefs about the NoS, the history of science and, eventually, the scientific content (Höttecke 2007). This general idea of an educational reconstruction, which takes into consideration not only learning and understanding science, but also its history and philosophy is outlined in Fig. 1.

Concerning the development of case studies the model "in action" does not intend a chronological consideration of these aspects. Instead, these aspects influence the didactical structuring, the design of a story line and the choice of NoS aspects to be highlighted in a case study. This idea is explained more deeply in the paragraph demonstrating the

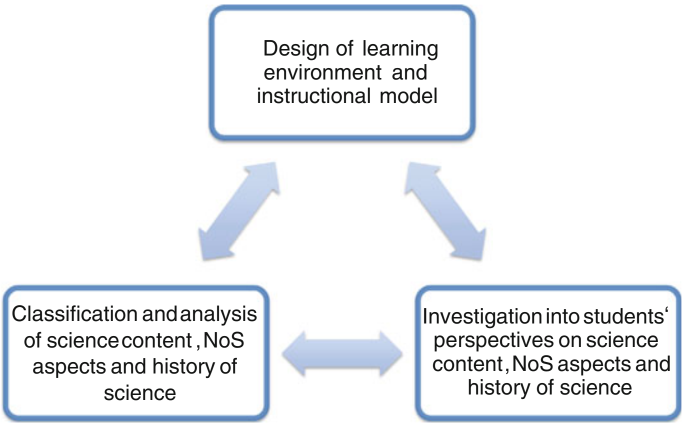

Fig. 1 Adaption of the model of educational reconstruction for the purpose of designing case studies for teaching and learning with HPS (Duit et al. 2005; Höttecke 2007)

development model of HIPST below. The enrichment of the model of educational reconstruction means *applying* history and philosophy to science teaching and learning instead of merely teaching history of science as something given as Allchin (1992) points out: "we cannot merely import historical material without attending its new functional context". He finally strives at a functional use of HPS in an educational context together with others (Rudge and Howe 2009).

Such a functional use of HPS for educational purposes has to balance several requirements: the science content has to be curricular relevant, the history has to display general characteristics of science instead of purely idiosyncratic episodes, a whiggish approach of teaching the history of science has to be avoided (Butterfield 1931; Allchin 2004). The latter means that "history" is merely used for interpreting the past in terms of ideas of the present. One-dimensional stories of scientific success may be a consequence. Finally students' perspectives on and interest in science and its history should be enhanced. This actually means that a multiplicity of perspectives has to be considered: the researchers' (science, history and philosophy), the science teachers' (content to be covered, manageable instructional models) and the students' (interests, prior beliefs and ideas). The practice of such an approach is described in our development model.

4 Student-Centered Activities for Teaching and Learning HPS

As mentioned above research about students' interest and motivations towards studying science at school-level has indicated that students have probably little interest in activities like reading texts and listening to talks. Therefore, the project group has focused on the development and application of methods for teaching and learning with and about HPS, which are more likely to raise students' interest, facilitate cognitive and metacognitive activities, creativity and reflective thinking. Student-centered activities for HIPST are based on the mediation of two approaches, which both have been advised for teaching and learning about the NoS: Teaching HPS with historical replicas (e.g. Heering 2000, 2003a; Höttecke 2000; Rieß 2000) and guided inquiry learning (e.g. Schwartz and Crawford 2004; Lederman 2004). From the various instantiations of inquiry based learning we chose to adopt a guided approach, since research indicates a guided inquiry approach to be superior to approaches relying on minimal guidance (Kirschner et al. 2006). Activities for reflecting explicitly on the NoS are regarded as central means for an enhancement of students' understanding (Khishfe and Abd-El-Khalick 2002; Lederman 2004, see also paragraph about the reflection corner method in this paper).

We consider the role of experiments for history of science in science teaching as crucial. Curricula and standard documents of science education usually stress the importance to design activities and methods which guide students' reflections on their own experimental practices and experiences. Ideas and actions of past scientists can be used as guidelines for the design of learning activities like open-ended inquiry. Since our work is based on an HPS framework students will relate and compare their own experiences with those described by scientists of the past. The HIPST approach means embedding guided inquiry activities in instructional designs for teaching and learning with and about HPS. If problems, actions or ideas of past scientists provide a guiding framework for student-centered activities, the students may act similar to historical researchers. They explore how scientists of the past may have designed and stabilized their instruments, how they developed and interpreted evidence and how they may have tried to convince colleagues of the credibility of their own research by using experiments as rhetoric devices.

Such an approach is demanding. Methods for scaffolding and guidance are needed even more if science teachers and their students appear to be inexperienced with inquiry learning or with student-centered methods in general. History may help teachers to balance the openness of inquiry approaches by identifying research questions or by supporting their students in planning and designing experiments. Historical sources like letters, excerpts of laboratory diaries or research papers of past scientists may serve as additional guideline next to direct instructions by the teacher. Finally, scientists' actions of the past scaffold students in coordinating observations and inference. This is just a selection of processes of inquiry as stated by several national standards documents, which can be guided by the well-directed use of history as a supporting agent for the design of open-ended inquiry activities.

Within our approach the teachers prescribe the general topic for teaching and learning, together with several appropriate inquiry activities. He or she also co-decides on the historical context in which all learning activities are embedded in. Following the replication method (see below) most of the material will be taken from the chosen scientist or group of scientists of the past. The respective research question(s) set the starting point of students' investigations which are designed and planned by themselves. They are supported in their work and in the interpretation of their results by instructional material and teachers' guidance.

Activities of the students are influenced by the scientific work of past scientists, how they performed experiments, interpreted experimental evidence, drew conclusions and created theoretical ideas. The role of the teacher during this phase will be to offer general support like scaffolding, modeling and coaching according to the model of cognitive apprenticeship (Dennen 2004). We include scaffolding strategies like activity-specific help cards, which the students may ask for, if they will have any problems or need any further support. Help cards provide information about the historical investigation and scaffold students' cognitive activities as well as their material research. Instructional material and help-cards together represent a frame of reference for the students to reflect on the development of their own ideas, their strategies of solving problems, and their coping with uncertainty and developing solutions. These reflections have to be generalized in the end to highlight overall concerns about the NoS and the nature of scientific inquiry.

5 Creative Writing for Understanding Science and Scientists

Creative writing is a rather well known method to enhance students' understanding in drama education (e.g. Scheller 1998). Students are asked to write letters, diary entries, dialogues, comments, depictions or short biographies from the perspective of a fictitious character. The method ensures a high degree of empathy with the character at issue. Moreover, ideas, fantasies and perspectives of the student necessarily shape the interpretational process and give rise to a deeper understanding of the character, its internal conflicts and general situation of life. Creative writing therefore takes into account the learners' perspectives and takes his or her ideas quite seriously. Through writing they explore their own understandings of their ideas on the NoS as well as of scientific concepts. In this respect the method is of relevance for science education in general and for teaching and learning with and about HPS in particular. From a constructivist perspective the ideas, beliefs and attitudes of students are a necessary starting point of meaningful learning and their conceptual development. Within the German HIPST group we make effective use of this method, since students are asked for reflecting critically on events of the history of science.

General reflections about the NoS are embedded in historical contexts. They are strongly related to the interpretational ideas of the students. For example, they may write short interviews with a scientist of the past on general topics like "How does science generate new knowledge?" An example in the box below illustrates how creative writing activities might be used for teaching and learning about the NoS. It originates from a case study about the experiments of Charles dú Fay (documented by Priestley 1775) who arrived at a general rule of electric attraction, communication and repulsion via explorative experimentation (Steinle 2004). In our view, appreciation and mastery of a special language for talking about science is a necessary aspect of the NoS. Accordingly, students should achieve a basic understanding of different kinds of knowledge in science. Researchers have stressed the importance of understanding the general meanings of the terms law and theory (e.g. Lederman et al. 2002). Therefore, the creative writing activity asks the student to reflect on an adequate description of the knowledge dú Fay had developed. Additionally the activity supports the students' reflective thinking on the general character of different kinds of knowledge in science. While rules and laws express regularities and relations between observable phenomena or entities, theories are inferred explanations of large sets of phenomena (e.g. the kinetic theory of gases).

Imagine you receive the following letter from dú Fay:

My dearly esteemed colleague,

Surely you have heard of the astounding results I have arrived at through many experiments

Nevertheless I will summarize:

1. *My observations of the behavior and movement of electrified bodies can be very well described by the sequence attraction-communication-repulsion*
2. *I am sure that all my observations can be explained by the existence of two different kinds of electricity (I call them glass and resin electricity)*

Perhaps, I may kindly ask for your assistance:

It has been suggested here and there, that there may be different kinds of knowledge in science. "Laws" and "Theories" were two of them. What a marvelous idea, since I myself deeply feel that my results are of different character! However, I am not sure how to classify my own results! Are they more of a law or more of a theory? How should I justify my claim, if I present what I have developed? I am in fear of publishing anything incorrect. My reputation as a honorable man of science might be damaged. Therefore, I would be eternally grateful, if you were to help me to correctly classify the knowledge I have generated

Yours, with my kindest regards,

Charles dú Fay

Helping-card

Your response could begin like this:

Dear Friend and Colleague,

I have studied your research with great interest. In everyday life, the terms 'law' and 'theory' are often used quite differently from science. But your results can be very easily classified, because there are certain aspects which clearly apply for scientific laws and others which apply for scientific theories. I will try to classify your results regarding these two terms…

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6 The Role of Role-Play Activities

Another important activity for exploring science is role-play. This student-centered method has been recommended for fostering a better comprehension of NoS (BouJaoude et al. 2003). Students explore conflicts among scientists, learn about the reasons for scientific controversies or ways on how to settle them. Moreover, the method supports students in developing empathy with scientists of the past (Ødegaard 2003; Duveen and Solomon 1994).

Role-play activities in science education based on HPS serve multiple purposes. The physical, emotional and cognitive immersion in a physical context enhances the understanding of complex scientific concepts (Taylor 1987). Danby and Upitis (1988) are referring to an increase in students' ownership towards content to be learned, if they are actively engaged in its representation.

McSharry and Jones (2000) have suggested the distinction of the uses of role-play in science classrooms by the categories of analogical, metaphorical, and simulating activities. In the following we will discuss the method of role-play along these three categories.

6.1 Analogical Use of Role-Play

Students engaged in *analogical* activities may take the role of physical entities like atomic particles, electrons or fields. In this case relevant aspects of physical properties are mapped onto physiological or social elements (Aubusson and Fogwill 2006). This method is more common in primary and lower secondary education. It can be used for instance to explore models in science. Within an HPS approach it may serve as a method for the representation of models changing over the course of time. The differences between different models of electricity can be displayed for example.

6.2 Metaphorical Use of Role-Play

The *metaphorical* use of role-play aims at the re-conceptualization of historical events and settings in science, the state of mind of scientists, their ideas and social relations. Students need to analyze and evaluate a situation thoroughly (e.g. the controversy between two scientists or groups of scientists). Instead of discussing the students' interpretations of science as a social enterprise, they are asked for creating a monument of the setting, controversy or event at issue. The method originally stems from drama education (e.g. Scheller 1998) and is used by us to engage students in an analysis of NoS issues at hand.

A monument or human sculpture usually is built by a single student as a "director" of the activity. All other students serve him or her as passive "actors" or respectively as raw material for building a monument. They are "passive" since they have to execute the instructions of the director accurately and without talking or expressing own ideas. The director is the only one who gives clear advice on how the actors shall pose and what feelings and attitudes they shall express with their bodies and faces. The method works best if the director is allowed to carefully model the monument or sculpture with his or her own hands. When the monument is finally built and "frozen" in such a way, the director asks each of the actors to express one typical sentence which expresses ideas, feelings, fantasies, beliefs, attitudes or any other aspect of the personal or social situation. A director may illustrate or even allegorize a scientist being in trouble with anomalous data or nervously preparing an important presentation. If social situations among scientist are demonstrated the students may display their ideas on communication, negotiation, exchange, struggle or even fight among scientists. Finally all students are invited to make comments on the monument or freeze sculpture and explain how they agree or disagree with the director.

We call the demonstration of an abstract or allegoric situation a monument (similar to a monument on a marketplace). A freeze sculpture instead displays a real-life situation (similar to stopping a film). Such a body-centered activity is a powerful tool for demonstrating and visualizing students' ideas on the role of beliefs, attitudes, emotions or social interactions in science.

The following example exemplifies the method. It is extracted from the case study "Traveling Showmen—Electricity, Entertainment, and the Construction of Scientificality" written by the authors. The case study generally deals with the problem of demarcating science from non-science. We have designed an activity for learning about this NoS issue. Basically, one can start on this issue from an epistemological or a social perspective (Zemplén 2009). We agree with Zemplén's strong consideration of the social without neglecting the epistemological aspects. The activity here is heavily based on the work of Hochadel (2006) and deals with the controversy of Georg Christoph Lichtenberg, a well-known and honorably natural philosopher of the 18th century, and his contemporary Martin Berschitz, an instrument maker and itinerant lecturer.

In 1770 Lichtenberg became professor for Physics, Mathematics and Astronomy at the University of Göttingen. He was well-known among contemporary colleagues like James Watt and Joseph Priestley. In 1793 he was elected a member of the Royal Society in London. Lichtenberg did research in many different scientific fields, including geodesy, meteorology, astronomy, and chemistry. Less is known about the life of Martin Berschitz. He began his career as an untrained assistant ("helper", as Lichtenberg wrote) in electrical demonstrations at the emperor's court in Vienna. Berschitz offered a great deal of services like fixing and selling electrical apparatus or applying medical-electrical cures. He used to be a well-known German electrifier, most of all because of his spectacular and enjoyable demonstrations. Berschitz's first encounter and consequent acquaintance with Lichtenberg was not always an advantage for him, even though he took some profits from Lichtenberg's recognition. At least in the beginning, Lichtenberg was ready to teach and support him. Later he changed his mind and claimed: "All of his experiments already have been carried out by myself". According to Lichtenberg's perception, Berschitz gradually had become too self-satisfied, pompous and dishonest. Lichtenberg finally stopped responding to Berschitz's letters. In addition, he recommended to the city of Hannover not installing Berschitz's lightning rods as Lichtenberg generally dismissed the use of lightning rods sold by those who did not fully understand the field of electricity:

> Such people cannot be responsible for the protection of public buildings and powder magazines. Instead, one should seek advice from those who have completed an appropriate course of study in electricity.

Lichtenberg often ridiculed electrifiers like Berschitz. According to him they were "wandering physicists, who should be called, in analogy to street musicians, the buskers of science".

The story of Berschitz and Lichtenberg highlights the general problem of demarcating science from non-science, or more generally, experts from non-experts. The latter might even be experts in fields close to science—skilled instrument makers, for example. The problem of demarcation is exemplified as a *social* instead of an *epistemological* problem. Disputes in this setting do resemble controversies from everyday life which students already know. They have of a variety of experiences on their disposal with problems like

"Who is right?", "Who is more competent?", "Who has the power to define standards?", "Who is more trustworthy?", "Who is an expert in…?", or "Who's got a higher social status?".[5]

The teaching unit starts with an introduction to the biographies of Lichtenberg and Berschitz. The students explore further background information and the general problem of how to define trustworthiness in science. Then, they are asked for building either a series of monuments or freeze sculptures which display their understanding of the conflict. Each of the monuments or freeze sculptures will be discussed in order to explore the social aspects of the demarcation problem.

The method allows a "hermeneutical" use of history of science. Students' own initial understanding is based on historical background information as well as on their own daily experiences. It serves as a starting point for the development of an enhanced understanding of social realities in science. Monuments and freeze sculptures are methods of expressing social relations among experts in science. The decision for or against such a teaching method has to be well legitimized. In this case a simulation of the Lichtenberg-Berschitz controversy within a role-play was not recommendable, since we know, and the students know as well, that Berschitz finally was inferior to Lichtenberg. Students would have taken roles in a quite unbalanced social situation with a priori feelings of superiority or inferiority as a consequence. According to our opinion, especially the latter situation should be carefully avoided, even more so with science teachers who are not very experienced in the guidance of role-play. Building monuments instead serves as a method allowing for an intense exploration of science as a social enterprise without involving students too strongly on an emotional level.

6.3 Using Role-Play as a Simulation of Science

A well-know type of role-play is the enactment or *simulation* of science in the class-room by (re-)enacting scenes from science (Aubusson et al. 1997). In a broader sense of the term inquiry-based activities are also a kind of role-play. Students behave (or should behave) in close accordance to the actions of scientists. According to Hart et al. (2000) students' understanding would be enhanced, if they will act out of the role of a scientist. This is even more important since research indicates a lack of mental engagement of the students, if they do experiments in a traditional way or even cook-book style. Therefore, students have problems to connect an experiment they have carried out to the respective theory (Solomon et al. 1996). As Tsai (1999) has shown

> […] empiricist learners placed greater emphasis on 'doing' laboratory work, following the codified procedures of science textbooks, and they believed that laboratory exercises made scientific concepts more impressive, acting as memory aids.

The active uptake of the role of a scientist may counterbalance this effect. If students are actively engaged in "simulating science" they explore phenomena, design instruments, plan and carry out experiments, collect and illustrate their data and draw evidence-based conclusions from an envisaged perspective of being a scientist. Usually students in such a learning environment will not easily accept the role of a scientist. Instead, when comparing themselves to scientists they regard themselves for instance as less accurate or less motivated.[6] Nevertheless, the experiences students are making while doing inquiry can

[5] See also the activities for teaching about the role of expertise in science advocated by Zemplén (2010).

[6] Preliminary result of an interview study of the authors.

serve as a rich resource for reflecting on typical actions of scientists and the NoS in general. Even if students do not identify themselves with scientists in many aspects, these perceived differences between themselves and the envisaged scientist may serve as a source of fruitful reflections on the nature of scientific inquiry.

Role-play activities interpreted in a narrower sense (excluding inquiry) strongly resemble methods of drama education. Students work in small research-groups. They hold conferences or prepare panel discussions. There they present their work and findings, demonstrate and justify their results and conclusion. If they write about their results along the idea of writing a scientific paper, they can even peer-review each other's methods and results and reflect on the norms of quality management (e.g. peer-review) in science. Such activities where students put themselves into the role of scientists will expand their notions of scientific activities and guide their future experiences. The simulation of controversies in science for instance is a commonly advocated role-play activity in this sense of the term (Bell and Linn 2002; Niaz and Rodriguez 2002).

Role-play activities in general are methods for exploring the conceptual, epistemological, human, emotional and social aspects of science. Students can practice role-taking, argue from different perspectives and reflect on the role of evidence, prior knowledge, theories, norms and values or even social networks and power in science. Since role-play itself is a social enterprise, it is most of all a useful method for demonstrating and reflecting on science as a social endeavor.

7 Replications of Historical Apparatus

In our project several historical apparatus have been re-constructed as working replicas for the enrichment of teaching science with HPS. Teaching experiences with such replicas have indicated that the replication-approach is fruitful for teaching on school level (e.g. Heering 2000), for designing exhibitions about the history of science (Heering and Müller 2002) and for teacher training (Heering 2003a; Rieß 2000). Replication has even been demonstrated as a successful method for doing research about the history of science focusing the procedural character, situatedness and contingency of experiments in science.[7]

According to the method of replication, measuring instruments and experimental setups of the past are re-constructed and re-enacted in close accordance with historical sources (Heering 2007; Höttecke 2000, 2001; Sichau 2000a). The general advantage of replication as a method for learning is its high degree of authenticity and contextualization. Furthermore, unlike common devices in science teaching, the replicated instruments in our project are almost exclusively constructed as devices of genuine scientific research, instead for unambiguously demonstrating already well-known phenomena or laws. Research apparatus might even be notoriously fault-prone and therefore provide opportunities for learning how to stabilize natural phenomena or how to separate signals from noise: Practical skills and material manipulations have to be learned and explored in close accordance with a theoretical understanding of the instrument and the understanding of the phenomenon itself.

Such a way of manufacturing meanings from experimental results, material procedures and theoretical comprehension in science has been described as an *interactive stabilization* (Pickering 1989). The observations students have made and the data they have generated with the help of the replication method have to be interpreted: The generation of evidence

[7] E.g. Heering (2007), Höttecke (2001), Sibum (1995), Sichau (2000a, b).

is an act of interpretation and interactive stabilization. In this respect we introduce the procedures of "work-bench science" to science learning. Success in scientific research often can be achieved only if a theoretical understanding of a phenomenon, the technical construction and theoretical background of an instrument, the observations made, the data generated and the material procedures applied are brought into a coherent view. Thus, the method of replication gives rise to reflections about the nature of observation and the role of instruments for establishing new knowledge in science.

As a sources for studying the material culture of the natural sciences replicated instruments lead to insights about the concrete experimental practice of scientists of the past (Heering 2000; Höttecke 2000, 2001; Sichau 2000b), opening up ways to connect this practice with the culture in which it was embedded. Materials which are characteristic for a given time can be explored. Sulphur, glass, resin, shellac, and even spermaceti were important materials for studying the nature of electrical phenomena during the eighteenth and nineteenth century. This aspect of the history of science so far has hardly been considered as an important feature of science or the NoS (Figs. 2, 3).

For most of the developed case studies replicas play a major role. One example may exemplify what has been discussed above. It concerns the sulphur globe developed by Otto von Guericke (case study written by the authors of this paper: "Otto Guericke—Forces, Analogies and the Quality of Scientific Instruments"). Guericke (*1602, †1686) is very well-known for his invention of the vacuum-pump and the famous evacuated Magdeburg Hemispheres for demonstrating atmospheric air pressure. The sulphur sphere served Guericke as a model of the earth. After rubbing the sphere with his hands it attracted light particles. He describes how light down feathers are first attracted to the sphere and then repelled after they had touched it (success depending on "atmospheric conditions" as Guericke alluded). Guericke regarded the attractive powers he had observed as a demonstration of the attractive powers of the earth. He furthermore speculated about the nature of repulsive powers acting on the moon (Guericke 1672).

The replicated instrument discloses problems and pitfalls of this early device for producing electricity by friction. Even though a feather is easily attracted to the sulphur sphere, repulsive forces cannot be observed with the same ease. Contrary to the expectations of science teachers and their students, it may even take several minutes until the little arms of a feather slowly start pointing upwards. Only a patient observer who resists

Fig. 2 Otto v. Guericke's sulphur sphere—floating down feather caused by electric repulsion

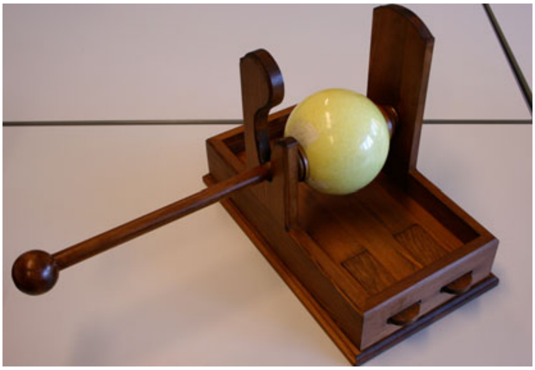

Fig. 3 Replication of Guericke's sulphur sphere made by W. Engels

further manipulations observes after due time a repulsion of the feather. Such a slow and gradual emergence of an anticipated phenomenon contradicts the expectations of someone who is used to perform pre-stabilized experiments with modern materials. Copper for instance does not produce any noticeable delay in electrical conduction, but the down feather does. Success with Guericke's sulphur sphere will therefore not be established before one has learned to overcome the expectation that electric conduction is only allowed without any delay. Either way, it means patiently waiting until the phenomenon slowly occurs. Compared to frictional electric machines of the late 17th century Guericke's sulphur ball is far from being easy to handle. For him properties like the mass and mixture of the sphere did matter the most. In the beginning of the 17th century natural philosophers just had a limited knowledge about materials and their electric properties.

It was not Guericke's intention to construct "the first electric friction machine". Nevertheless, his successors aimed at improving such instruments, generating electric phenomena more efficiently. Students' experimental experiences with the replica of Guericke's sulphur sphere give way to a follow-up activity: the students are asked to creatively develop their own ideas on how to improve Guericke's sulphur sphere. Even though the students might have failed to observe the electric repulsion described by Guericke, they are motivated to develop criteria which characterize the quality and usefulness of instruments in science. Such criteria guide the design of their own instruments. Guericke's experiments and their re-enactment in the classroom serve as starting points for a general discussion about the quality of instruments in science and how "quality" may be best defined. Next to purely material qualities like weight and durability, the students will come up with criteria like cost and affordability, potential for reproducible experiments or ease of use. Each of these criteria is a fruitful base for discussing aspects of the NoS. Here the instrumental use of history becomes evident. History is not used as an assumed re-narration of past science, but used instrumentally for arranging complex learning environments where learning science as process and content, learning about general aspects of the NoS and the nature of scientific inquiry are enabled.

Even though we have developed a series of replicated instruments for teaching and learning purposes, it is obviously hard to offer unlimited access to them. So far we have developed several experimental kits with materials for teaching the Gilbert case study, six sulphur globes according to Otto von Guericke (early 17th century), several electrical bells, one apparatus to demonstrate electric conduction according to Stephen Gray (early 18th century), one functional model of an electric friction machine and one inclined plane according to Galileo Galilei (16th century).[8] In order to allow easy access to the instruments for educational purposes several short films have been produced which demonstrate the instruments in action.[9]

8 Explicit Reflections on the NoS at the "Reflection Corner"

As stated above learning about the NoS is unlikely to be effective, if students do not reflect explicitly on the NoS (Khishfe and Abd-El-Khalick 2002; Lederman 2004). Hence, another challenge for the development work was to design applicable methods for addressing the NoS explicitly and reflectively. Schwartz and Crawford (2004) have suggested classroom discussions, guided reflections and specific questioning as instruments for meaningful reflections and generalizations on NoS issues. They admit, however, that teachers need a significant amount of knowledge about the NoS and practice in using appropriate scaffolding tools. Without professional development in this field, science teachers are in danger to fall back to conventional teacher-centered methods. Teachers should therefore apply pedagogical strategies for addressing the NoS explicitly, which means incorporating NoS as a planned and intentional instructional outcome of science lessons (Rudge and Howe 2009).

The German HIPST group has designed such a pedagogical strategy, which supports teachers facilitating their students' reflections on the NoS. The method is called *reflection corner*. It aims at a generalization of highly contextualized instances of the NoS towards the development of broad ideas about science. Thus, the students need to separate at first the level of thinking about the details of a case study and classroom activities from the level of abstraction and general ideas about science. This separation is accomplished by asking the students from time to time to direct their attention to the back of the classroom, now called reflection corner. This will be the designated space for reflections and generalizations on the NoS. While the front of the classroom provides a space for students' multiple learning activities, the back of the room will be reserved for explicitly reflecting on the NoS. The separation of different spaces in the classroom for cognition and metacognition raises the students' awareness for distinguishing different types of cognitive activity. The reflection corner helps them to draw comprehensive insights about the NoS from the case study at stake. Arguing for such a separation does not discredit other methods for addressing and generalizing the NoS. Clough (2006) or Bannerman (2008) for example have presented continuous scaffolding activities which demand a high level of expertise and reactivity from teachers. In the context of the HIPST project, however, we had to develop methods for addressing the NoS which strongly support teachers with limited expertise in moderating explicit reflections on the NoS. A comprehensive internal structure of the method appeared to be fruitful. Predefined NoS aspects for each of the case studies further on supported the teachers. Teachers therefore can use the reflection corner as a "module" among others for planning and structuring their science lesson. Using the reflection corner in such a way fits to teachers' lesson planning behavior (Shavelson 1983).

The reflection corner starts with a central and rather general question. It should be answered by the students again and again throughout a case study, each time from different

[8] The instruments mentioned here are those assembled for HIPST. Several others from different branches of science and different centuries have been replicated earlier. See http://www.histodid.uni-oldenburg.de/22139.html.

[9] Please apply to any of the authors for getting a copy. Further films have been produced by the European projects STeT (http://www.histodid.uni-oldenburg.de/30702.html; 10-05-2010) and MAP(http://www.histodid.uni-oldenburg.de/22886.html; 10-05-2010).

perspectives depending on what they have recently learned about science, its history or philosophy. Thus, the general question serves as an advance organizer for directing the students' awareness to the central objective of teaching a case study: to enhance students' understanding of the NoS. General questions might be:

- How do scientists generate new knowledge?
- How do scientists work?
- How do scientists achieve success in their field?
- Is there anything specific about science?

Of course, such questions are quite broad and general. This is dangerous since students might be overstrained in tackling them in this form. Two methods have proven of value for avoiding this danger: Think-Pair-Share and explicitly addressing resources of reflection.

The method of think-pair-share is commonly used in teaching for encouraging and slowing down processes of reasoning, developing new insights, and sharing ideas with others. The key question at issue will firstly be answered by each of the students. A phase of sharing and revising ideas with a partner follows. Finally the partner-groups contribute to a general classroom discussion.

Students can make use of three major resources for reflecting on the NoS:

- the students own activities, results, solutions, ideas and thoughts (e.g. while doing inquiry activities, working with replicas, or role-playing) in the preceding lesson
- information about the actions, cognitions, beliefs, and feelings of a past scientist as presented by texts, instruments, descriptions of experimental procedures, pictures or films
- the broad societal and cultural context at issue (e.g. provided by texts, interactive media, brief narratives of teachers or students' own investigations).

Further support can be given by addressing these three resources of reflection explicitly by the teacher, either by written activities or key questions. Table 1 illustrates how these three resources might be explicitly addressed.

The teacher limits him- or herself to the moderation of the discussion. He or she might cluster ideas of the students on cards at the blackboard or with similar techniques.

The last step aims at a generalization of students' ideas, while the teacher asks them for further manifestations of their generalized "ideas about science". Generalization can be achieved by relating students' activities to those of professional scientists and by relating the exemplars of past science presented in that case study to present-day science as perceived by the students. If the students for instance will generalize the idea of controversies and conflict among scientists of the past, the teacher would ask the students, if they admit controversies today characterizing science in the same manner as in the past. The teacher furthermore encourages his students to give a wide range of examples of controversies and arguments among scientists.

In order to give the students opportunities to reflect on the NoS in a more specific manner, a second phase of explicit reflections at the reflection corner may follow. Here general questions are asked focusing on certain peculiarities of sciences that can be learned along with the episode or case study at issue. Two examples will highlight this kind of use of the reflection corner:

Example 1 Some students in various groups have re-enacted how a scientist carries out and documents a plethora of experiments and afterwards assumes a scientific law accounting for specific patterns in his or her observations.

Table 1 Resources for reflecting on the NoS explicitly at the reflection corner

Resource	Students' own actions and cognitions	Actions and cognitions of a scientist of the past	Societal and cultural context of past science
How to address the resource:	If you think about what you have done during the activity YYY or how you have contributed to our discussion today?	If you think about how XXX (e.g. William Gilbert, Benjamin Franklin) went about it and solved the problem?	If you think about how scientist like XXX (e.g. William Gilbert, Benjamin Franklin) did live and work in their country and their time?
Further encouragement	• You have written lots of interesting entries in your lab book today • You have solved the problem on various ways • The results of the groups differed significantly • You have argued with each other. Finally you trusted the results of Susanne • You did rely on previous knowledge while interpreting the data • You have achieved an unexpected result • You did not accept a refutation of your assumption • First you trusted your results and then you became unsure • …	XXX… • Kept a research diary • Set up assumptions Was looking for regularities • Developed a new idea • Had to defend his ideas • Wrote many scientific articles • Had to justify his results before others • Constructed and sold scientific instruments • Was famous for being an excellent experimenter • Was particularly interested in seafaring • Was very religious • Was a well-known politician and economist • Was regarded as a gentleman and serious scientist • Was ignored by his colleagues • …	• People were very much dependent on exact navigation at sea • The geocentric view of the world was predominant • It was regarded as inappropriate for women to work as a scientist • Scientific societies decided on the recognition of research results • Scientists like XXX had to perform their experiments in public • The reliability of XXX depended on the advocacy of honorable men of science • The British Empire was very interested in protecting their vessels against lightning strokes •…
	What does this mean for our general question?		

A possible question for reflection could be:

> We have seen that XXX firstly carried out a lot of experiments before setting up an assumption. Is it also possible to develop scientific knowledge in other ways?

This example introduces the idea that there is no such thing as *the* scientific method. Moreover, it encourages students to reflect about a multiplicity of possible relations of empirical evidence and inference in science.

Example 2 The students read (a fictitious) letter of a scientist. There he describes how he has presented his results to the representatives of a scientific society. The members of this honorable society doubted the reliability of his results, because they did not trust the scientific instrument he had used. A possible question for supporting the students' reflections could be:

> We have seen that XXX's results were rejected by his contemporaries. What is the role of a device or instrument for the acceptance or rejection of results, theories or ideas of a scientist? What characterizes the quality of a device or instrument from a scientific perspective?

The second example demonstrates that scientists have to justify their results within a scientific community. Trust and distrust are essential factors which can be based on quality criteria for scientific devices or their publicity.

The *reflection corner* aims at dealing with the inherent problems that students have in abstracting from the level of tangible classroom activities onto the level of generalized ideas about science (Loughran et al. 2003). The internal structure of the reflection corner guides students' abstraction and provides opportunities to connect classroom context with reflections on general aspects of the NoS.

9 A Symbiotic Strategy for Developing Case Studies About HPS

Curricular innovations like HPS hardly enter the practice of school science teaching, if not measures will be adopted for overcoming the obstacles preventing this innovation from its wide implementation as they were stated in the introduction of this paper. Student-centered activities, creative writing, role-play, working with historical replicas at school or even establishing a reflection corner in the back of the classroom are far from being the mainstream of science teaching in most countries. Even if overcoming all obstacles at once within a single project is illusory, many of the obstacles mentioned in the beginning have been taken into account:

- We do expect that the culture of teaching science and physics in particular can be changed only slightly and over the course of extended periods of time. Comparable projects for implementing a curricular innovation have stressed the merits of integrating teachers into the development work. We are aiming at a tight fit of the case studies to the practice of science teachers, their ideas and beliefs as far as possible. The integration of teachers into the development process ensures this need.
- The lack of teachers' adequate experiences and skills in teaching HPS according to our ideas is an obstacle, which is balanced by continuing skill enhancement of the teachers involved. The developmental methodology considers teachers as situated learners (Ostermeier et al. 2010). Their learning and professional development is located closely to their daily professional demands.
- Many standards and curricula do not substantially support HPS, but are content-driven in a traditional way. We have developed case studies as examples of how to integrate different curricular objectives like learning science content, HPS and the NoS. Thus, the case studies are not only designed for teaching purposes, but also as a tool for convincing curriculum developers about the feasibility of our approach.

The development model will now be outlined in more detail.

Our work is based on and inspired by participative action research (Eilks et al. 2004) and action research models (e.g. McKernan 2006). These models consider curricular innovations to be explored and developed in circles of retrospective understanding and future action. Ideas, concepts and strategies of teaching are planned, evaluated and reworked cyclically. A strong participation of teachers is characteristic. The model of Eilks et al. (2004) additionally stresses the integration of different kinds of expertise into the developmental process in order to overcome differences of norms, rewards and working arrangements which separate the communities of teachers and researchers from each other (Huberman 1993).

Strategies for developing and implementing curricular innovations which integrate teachers as experts among others have been called *symbiotic* (Gräsel and Parchmann 2004). Such strategies are delineated from traditional top-down strategies which are characterized by adapting curricular innovation to the objectives of curriculum developers and researchers emerging from results of research and development. But, the problem of top-down strategies is often a low degree of acceptance among teachers. To set the stage for successful curricular innovations the implicit values and commitments have to match the belief-systems of communities of practitioners in schools (Snyder et al. 1992). As has been shown for HPS strong long-term beliefs about epistemology, general attitudes towards science and general beliefs about teaching and learning of the teachers are in conflict with the above mentioned objectives (overview: Höttecke and Silva 2010) resulting in an insufficient implementation until today.

Within a symbiotic approach, however, the level of support of practitioners is intended to be high. Moreover, the level of professional development of practitioners which they achieve during the development and exploration of the curricular innovation increases. They have the chance to reflect on their own ideas and beliefs about science teaching in general as well as about the role of HPS in science teaching. On the other hand the participating researchers also have the chance to reflect and develop their ideas on the practice of teaching science. Additionally, the integration of science teachers into the symbiotic developmental model from the very beginning ensures a high degree of acceptance of its results in their professional field.

Researchers and teachers share ideas and perspectives. Both shape the developmental processes with their different kinds of expertise, knowledge and skills. Researchers contribute with their knowledge about history and philosophy of science or with general research findings about teaching and learning or students' prior conceptions and beliefs. They are responsible for structuring the developmental processes and for defining the key issues of meetings regularly held. They organize accompanying research for evaluation and revision of the material developed.

Teachers on the other hand contribute with their general didactic creativity, knowledge and skills based on their own teaching practice. They develop ideas and methods for teaching and learning, provide resources for evaluation and participate in accompanying research cooperatively. Furthermore, the model ensures that teachers develop ownership of new teaching practices (Eilks et al. 2004), which are not yet part of the current culture of science teaching: they have to moderate discussions and negotiations among students, they guide open-ended inquiry activities (van der Valk and de Jong 2009), instruct students for several kinds of role-play or moderate the students' reflections on the NoS at the reflection corner.

For HIPST a double-cycle model for the development of case studies has been chosen (Fig. 4). It comprises the following systematic steps:

A group of researchers and practitioners is constituted. In the very beginning they share their ideas and perspectives. Researchers for instance follow the idea of developing case studies for teaching and learning about NoS with HPS. They put strong emphasis on avoiding to fall into the trap of a whiggish approach of teaching HPS (see above). Therefore, researchers in the project emphasize portraying science as a human endeavor bearing controversial and multifaceted ideas, concepts, theories and experimental cultures, blind alleys and losers of science (Chang 2009) or rejected experiments (Heering 2003b). On the other hand science teachers make sure that their lessons will be effective and fun for their students. They define the "hard" boundary conditions of the developmental work: the scientific content to be taught in order to match their curricula and the amount of time they are willing to teach the case study at issue. During this phase researchers and practitioners together start identifying obstacles, boundary conditions, but also options and potentials of the development process. Based on this preparatory work the group decides on materials and case studies to be developed and explored in the future.

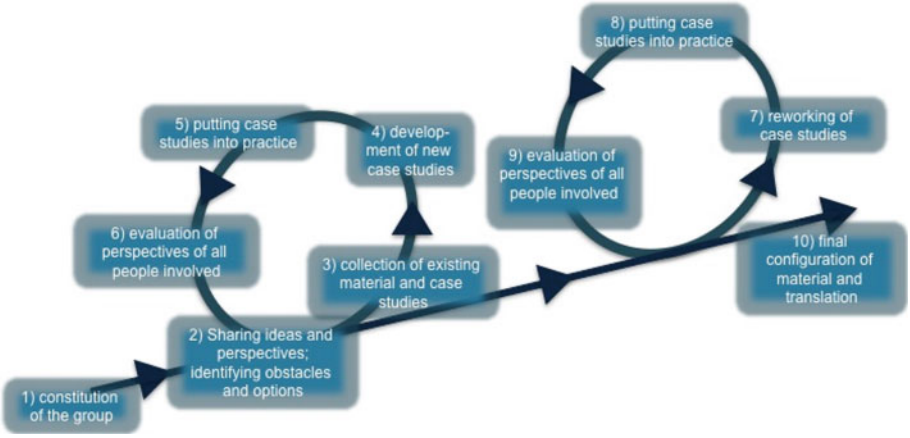

Fig. 4 Developmental model of HIPST

Subsequently a first phase of development of the case study follows. During this phase historical and epistemological issues have to be discussed as well as didactical and methodological aspects of teaching and learning. The teachers are responsible for carefully controlling and reflecting the usability of all ideas and materials developed from a practitioner's point of view. Researchers are responsible for providing clear-cut historical and philosophical background knowledge. Both expert groups are responsible for the educational reconstruction of HPS including didactical structuring and the development of student-centered activities. A first test of the case study including an evaluation follows. The tools of evaluation have to be adapted to the questions the whole group or the researchers have defined before. Single or group interviews with students, reflective interviews with the teachers having taught a case study, field notes, or video- and audiotapes are means of formative evaluation.

Based on a discussion of the results a reworking phase follows. After a second test and evaluation the development of the case study will be terminated. During this second phase of test and evaluation it is highly desirable to invite further practitioners to test the materials if possible. This procedure accounts for the fact that practitioners who have been involved in the first phase have developed professional skills and specific didactical knowledge and routines for using the case studies properly. Inviting further teachers from outside enables the group to learn more about how teachers use the materials offered to them. This procedure ensures that the material will finally be adapted in a way to support regular science teachers who have not been involved into the developmental procedures.

Obviously, the development process will be the more refined the more cycles the developmental model encompasses, but according to our experiences a double-cycle model sufficiently balances complexity and benefit. The cyclical structure of the developmental model has to be applied flexibly, since strong boundary conditions at schools often hamper numerous phases of evaluation and refinement. The developmental process ends with a final configuration of the material. For HIPST all case studies were additionally translated into English. Many case studies are even available in several other languages.

10 Structuring the Development Process

The "heart" of the German HIPST activities was a so called thematic working group comprising several physics teachers and researchers from the Universities of Bremen, Oldenburg and Hamburg. The group met about once a month during the runtime of the project. All participants were responsible for the collection, development, translation, adaption and publication of case studies. The group decided on focusing on the development and adaption of case studies for physics learning on school level, because the main expertise of all members of the group was located in this field. During twenty meetings several case studies were developed (see Table 2).

Four central issues were permanently taken into account during the development process (step 4 and 7 of the model outlined in Fig. 4):

10.1 Gathering Options and Restrictions

Curricula, teachers' time-tables, classes available for testing the material or personal preferences, doubts and worries of members of the group are discussed. The group decides on a general topic of development (e.g. mechanics for 8th grade).

10.2 Exploration, Immersion and Storyline

Exploring the field for available teaching and learning resources; immersion of the participants into the history of science (e.g. literature, pictures, biographies) and identification of central scientific concepts and ideas including the NoS; developing a preliminary and episodically storyline representing relevant historical information along a narrative about science and its development. Major ideas, scientific concepts and problems of the topic should be highlighted by the historical context.

10.3 Discussion and Didactical Structuring

Members of the group develop and negotiate ideas about the didactical structure of the case study (e.g. types and sequences of activities and/or scaffolding for students). Aspects of learning (e.g. students' prior conceptions and beliefs) as well as of formal organization (e.g. amount of time for teaching a case study) are taken into account. Organizational aspects like duration of lessons and activities are considered. Activities and materials will be allocated to the individual stages of the storyline.

10.4 Teachers' Professional Development

acquisition of relevant knowledge, concepts and teaching skills (e.g. role-play activities, guiding and scaffolding inquiry activities, moderating the reflection corner) is supported whenever necessary, for example through training or manuals; experiences made by the teachers during their own teaching of case studies are reflected in the group and lead to further professional development of all members of the group.

Table 2 presents an overview of the case studies and the languages in which they are available. All of them are at least to some extent based on the approach of inquiry learning. The material includes historical background information, lists of objectives and of the NoS issues which may be targeted by the case study. All activities and teaching materials are

Table 2 Case studies developed by the German HIPST groups

	Title	Key words	Target population	Authors	Languages
1	*Episode 1 of the series: Historic-Genetic Introduction to Electricity:* "William Gilbert—Separating electrical and magnetic attraction under the magnifying glass of experiment"	Static electricity, electrical attraction, magnetism, magnetic attraction, lab diary, categorizing, sorting, William Gilbert	Secondary school students aged 12–15	Andreas Henke, Dietmar Höttecke, Falk Rieß	German, English
2	*Episode 2 of the series: Historic-Genetic Introduction to Electricity:* "Otto Guericke—Forces, Analogies and the Quality of Scientific Instruments"	Static electricity, electrical attraction, electrical repulsion, Otto von Guericke, sulphur ball, scientific instruments, analogies, Royal Society, Robert Boyle	As above	Andreas Henke, Dietmar Höttecke, Falk Rieß	German, English, Italian
3	*Episode 3 of the series: Historic-Genetic Introduction to Electricity:* "Charles dú Fay—Describing and Explaining Electrical Phenomena"	Static electricity, electrical attraction, electrical repulsion, Charles dú Fay, law, theory, vitreous electricity, resinous electricity	As above	Andreas Henke, Dietmar Höttecke, Falk Rieß	German, English, Italian
4	*Episode 4 of the series: Historic-Genetic Introduction to Electricity:* "Stephen Gray—Electrical Conduction on the wrong track"	Static electricity, electrical attraction, electrical repulsion, electrical conduction, conductivity, experimental set-ups, testing hypotheses	As above	Andreas Henke, Dietmar Höttecke, Falk Rieß	German, English, Italian
5	*Episode 5 of the series: Historic-Genetic Introduction to Electricity:* "Traveling Showmen—Electricity, Entertainment, and the Construction of Scientificality"	Static electricity, Lichtenberg, Berschitz, electrifiers, demonstrations, scientificality, scientific community, controversy	As above	Andreas Henke, Dietmar Höttecke, Falk Rieß	German, English
6	Moving Bodies: Lessons from Aristotle to Galilei about aspects of the nature of science	Aristotle, Galilei, early mechanics, inertia, idealization, role of mathematics in physics, inclined plane	Grade 8–11 (age 14–17)	Dietmar Höttecke, Andreas Henke, Anna Launus, Falk Rieß	German, English, Portuguese
7	Refrigeration technology	History of technology, refrigerator, methods for producing coldness	Grade 5–7 (age 10–14)	Veronika Maiseyenka, Anna Launus, Andreas Henke, Falk Rieß, Dietmar Höttecke	German, English

extensively and comprehensively documented. Thus, the case studies are designed in order to serve as a "pedagogical double-decker" (Petty 2009): to enhance teachers' professional development in the field of HPS and NoS and to provide ready-to-use instructional material.

11 Conclusions

This paper outlined strategies and methods for implementing HPS with special attention to the NoS in school science teaching. Among them were student-centered and open-ended activities like the combination of inquiry learning with historical replicas, role-play activities like constructing monuments and freeze sculptures, creative writing activities, and the reflection corner as a method for addressing the NoS explicitly and reflectively. Several case studies for teaching and learning science and about science have been developed, evaluated and disseminated. Case studies and teaching methods were both results of a symbiotic development model based on continuous collaboration of science teachers and researchers with equal rights, but different perspectives, expertise and duties. The major purpose of the HIPST project was to foster implementation of HPS in school science education on the level of curricular development, science teachers' professional development as well as networking stakeholders involved. Singular attempts like this project are far from solving all of the problems one faces, when striving for sustainable implementation of HPS. Nevertheless, some general conclusions can be drawn on the basis of reflected experiences with the HIPST approach.

The strong collaboration of researchers and teachers within a thematic working group has generally proven to be fruitful and of high value. Both expert groups agreed on having learned a lot from each other. From the teachers' perspective it has been stressed that the collaborative development approach offered numerous opportunities to reflect on one's own teaching practice. Teachers in the German group highly appreciated the fact that teaching materials were developed cooperatively. It has to be noted that the HIPST approach contradicts the teachers' everyday practice of preparing instructional designs and materials in isolation. Feedback from colleagues therefore is usually rare. Following a symbiotic strategy like the one discussed in this paper, the collaboration of the two expert groups strongly influence its products. The researchers in the group (and authors of this paper) clearly learned about boundary conditions at school (limitation of time, accessibility of resources, teachers' capacities to teach such an approach). Thus, both expert groups finally developed their professional knowledge and skills.

The case studies are highly informed by the history and philosophy of science and adapted to the practice of science teaches as far as possible. An instrumental use of HPS appears to be a key issue, since history and philosophy of science have to be reconstructed under an educational perspective. The adapted model of educational reconstruction (Duit et al. 2005) serves as a useful framework which guides the development of instructional models, materials, and environments for teaching and learning.

During more than 2 years of continuous collaboration not only potentials, but also problems and limitations of the approach became apparent. Innovative teaching methods like the ones developed by the project are usually far from the every-day practices, routines and skills of science teachers. Even those teachers involved in our project reported how demanding teaching science with HPS appeared to them. Extended means of professional development therefore are necessary. A wide implementation of HPS presupposes that large groups of interested science teachers will be supported continuously. We strongly doubt that selective vocational training is sufficient in order to enhance science teachers' professional development for teaching HPS. Change needs time and continuous professional development, as experience from other projects already has indicated.[10] We suggest that teachers are invited to join phases of repeated collective training. Problems which have been identified during the development of instructional models and materials or during their evaluation at school should be identified clearly. Scaffolding structures have to be developed accordingly, which support the teaching of historical case studies. This means that typical teaching skills have to be performed by the teachers like moderating open-ended discussions, analyzing and considering students' perspectives, scaffolding open-ended activities and guiding role-play.

Our project also taught us lessons about the transformation of instructional designs planned and intended to be enacted by teachers. Even if agreement about the design of a case study was achieved in the thematic working group, the teachers had to transform the planned and intended curriculum into a curriculum actually enacted in the classroom. During the project we learned that teachers individually put emphasis on some aspects of a case study while they neglected others. This "mangle of teaching practice" is currently not very well understood and might be highly influenced by teachers' individual skills, beliefs, curriculum emphasis and even fears. Further research is needed in order to understand such a transformative process from a curriculum intended to a curriculum enacted and finally to a curriculum learned by the students. The demands which teachers perceive when planning and teaching science with HPS are expected to be an important factor for the mediation of teachers' decisions for or against HPS.

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