

**Case Studies for Teaching and Learning
with History and Philosophy of Science**
Exemplary Results of the HIPST Project in Germany

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***Paper presented at the Tenth International History, Philosophy, and Science
Teaching Conference***

University of Notre Dame

South Bend, USA

June 24-28, 2009

1. Abstract

This paper aims at presenting exemplary results of the German working group of HIPST, a European project for development and evaluation of case studies for teaching science with history and philosophy. The project HIPST - History and Philosophy in Science Teaching - enacts collaborative development of case studies for teaching and learning physics. Over a course of 30 months materials are developed, evaluated and refined by thematic working groups of researchers and in-service teachers. The resulting case studies promote contextual, student-centred activities and include methods for explicit reflecting on the nature of science. The paper describes the teaching- and learning-methods adopted for the case studies. They will be discussed and justified. Secondly, a rationale for the collaborative development methodology is presented. Finally, a brief overview of the case studies and their main ideas will be presented.

2. Introduction

The implementation of HPS in school science practice is being advocated by many scholars with sound evidentiary reasoning (for an extensive list spanning the humanistic, educational or psychological domains see Höttecke & Rieß in these proceedings). They have made suggestions and developed structural models of how to construct historical case studies and narratives about the history of science, which foster conceptual change and learning about the nature of science (e.g. Irwin, 2000, Stinner, McMillan, Metz, Jilek & Klassen, 2003, de Berg, 2005, Rudge & Howe, 2007 who suggest adoptions to the model proposed by Monk & Osborne, 1997, Kubli, 1999). These suggestions are very helpful in providing insight into the teachers' role as a storyteller, the relevance of narrative techniques and the identification of relevant contexts and content for classroom activities. The development model of HIPST additionally integrates the perspectives and resources of science teachers. As has been emphasized elsewhere (Eilks, Parchmann, Gräsel, & Ralle, 2004) curricular innovations are more likely to be accepted by practitioners, if they are invited to shape the development and implementation of an innovation with their special views, beliefs, ideas and capabilities.

The boundary conditions of science teachers' actual practice and routines are considered as an essential factor, which has to be taken into account developing case studies about HPS (Höttecke, in print).

In the following it will be shown how researchers' and practitioners' perspectives are mutually integrated into a structured developmental process, which finally lead to the development, evaluation and refinement of historical case studies.

3. Innovative Methods for Learning with & about HPS

Research about students' interest and motivations towards studying science at school-level has indicated that students are less likely to be interested in activities like reading texts and listening to talks (overview Merzyn, 2008). 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 activity, creativity and reflective thinking.

Guided inquiry and HPS

Guided inquiry activities are embedded 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-centred activities, the students may act as historical researchers themselves. Guidance and scaffolding by the teacher is needed especially if students are less experienced with the method of inquiry learning or with student-centred methods in general. History may help teachers to balance the openness of the inquiry approach by identifying research questions, guide the planning and design of research procedures. Original documents can be assessed for additional information or for assumptions similar to one's own. Finally, actions of historical researchers scaffold the coordination of observations and inference. This is just a selection of processes of inquiry as stated by many national standards documents, which can be guided by the well directed use of history as a guiding agent within inquiry

The level of guidance may be characterized by identifying the main actors guiding or prescribing the different phases of inquiry teaching and learning (Bonnstetter, 1998). In historical case studies the main actors determining guidance or openness are either the teacher, the students or the historical context (e. g. the historical researcher in focus).

Within our approach the teacher prescribes the general topic like the study of electrical forces or moving bodies and several relating inquiry activities. He also decides for a historical context in which all learning activities are embedded. Following the replication method (see below) most of the materials will be provided by the historical researcher in focus. His (sensibly reconstructed) research question(s) set the starting point of students' investigation. The students are responsible for the design of the investigation themselves. Instructional material and teachers' guidance support them for planning and conveying their own investigations as well as interpreting their results. Therefore, activities of the students are informed by scientists of the past, how they performed experiments, got their results, theoretical ideas and interpretations. The role of the teacher in this phase will be to provide a support, which the students are free to ask for in case they need it. Scaffolding strategies include help cards, which the students are using if they have problems or lack any idea on how to proceed. Help cards provide information about elements of the investigation of the scientist of the past and therefore scaffold students' cognitive activities as well as their material investigations. As a result the students are carrying out data acquisition and analysis as well as drawing and presenting conclusions based on supportive evidence. Instructional material and help-cards together represent a reference for reflecting on the development of their own ideas, strategies of solving problems, coping with uncertainty and developing solutions. Finally, these reflections have to be generalized to overall concerns about the nature of science and scientific inquiry.

Replications of historical apparatus

Working replications of several historical apparatus have been constructed for the enrichment of teaching and learning. According to the method of replication instruments of the past are re-constructed in close accordance with historical sources (Höttecke, 2000, Sichau 2000). The general advantage of replication as a method for learning is its high degree of contextualization. Furthermore, replicated instruments are originally constructed as devices of scientific research. As a result replicated instruments often display natural phenomena and laws with a lower level of significance than instruments for demonstrating phenomena and laws in science teaching usually do. Therefore, replicated instruments provide opportunities for learning how to stabilize natural phenomena: Manual manipulations have to be developed in close accordance with a theoretical understanding of the instrument and the phenomenon itself. This way of

manufacturing and making meaning of experimental results, material procedures and a theoretical understanding of an experiment as a process has been described as an interactive stabilization in science (Pickering, 1989). Observations made by the students and data generated by a replicated instrument have to be interpreted in general terms of a wide understanding of the instrument, a theoretical backing and the actual procedures students develop. Observations and data do not count as evidence in a self-evident manner, but instead are the objects and results of an interpretational process of interactive stabilization. In this respect learning with replicated instruments is much closer to the way scientists are working at their benches than devices for displaying natural phenomena in science teaching usually are. The success of an experiment is neither a set of data supporting nor falsifying a hypothesis in a clear-cut manner. Instead, success has been achieved, if a theoretical understanding of a phenomenon and the construction of an instrument, observations made, data generated, material procedures and experimental skills are brought into accordance with each other. Since replicated instruments are characterized as devices for doing scientific research they are fault-prone and produce phenomena with less significance. A high degree of contingency of results is a consequence. Practices and routines of manual manipulations have to be developed by the students before success may be achieved. Thus, replicated instruments give rise to reflections about the nature of observations and data generation in general as well as about procedures and skills for doing experiments in science and the role of instruments in the construction of facts and knowledge.

As sources for studying the material culture characteristic for the natural sciences they lead to insights about the tangible experimental practice of scientists of the past, typical materials like sulphur or shellac, which have been important for instance in studying the nature of electrical phenomena during the 18th and 19th century.

Creative writing for understanding science and scientists

Creative writing is a rather well known method for the enhancement of students' understanding of drama (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 gives rise to a deep understanding of the character, its

conflicts and general situation of life. Creative writing therefore is a method to take the learners' perspectives and ideas seriously into account. In their 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 conceptual change. 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 nature of science are embedded in historical contexts and strongly related to the interpretational ideas of the students. For example, they may compose short fictitious interviews with a researcher on general topics like how science generates new knowledge or how his research may be typical for the way science works.

Nature of Science at the Reflection Corner

Schwartz and her colleagues (2002) have suggested classroom discussions, guided reflections and specific questioning as instruments for meaningful reflections and generalisations on NOS issues. They admit, however, that teachers need a significant amount of knowledge about the NOS *and* practice in using scaffolding tools throughout the reflection process. Without professional development in this field, teachers are in danger to fall back to conventional teacher centred methods. Teachers should apply reasonable pedagogical strategies for addressing NOS explicitly, which means to incorporate NOS as an intentional and planned instructional outcome of the science lessons (Rudge & Howe, 2007).

The German HIPST group 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 accounts on the NOS towards the development of broad ideas about science. Consequently the students need to separate the level of thinking about case study related details from the level of abstracting towards broad ideas about science. The separation is done by the students turning around to face the back of the classroom if the latter type of cognitive activities are required. While the front of the classroom provides a space for students' inquiry activities, discussions about the scientists and context at hand, their problems, ideas and

theoretical solutions, the back wall will be reserved for explicit reflections on the NOS as well as metacognitive reflections on one's own activities and cognitions. This latter space is called the reflection corner. The separation of different spaces in the classroom for cognition and metacognition raises the students' awareness for distinguishing different levels of cognitive activity. The reflection corner helps them to draw comprehensive insights about the NOS from their own activities and cognitions related to the case study at stake.

At first the students are asked for reflecting on their own activities, results, solutions, ideas and thoughts. During a second step their experiences are related to the information about the actions and cognitions of a past scientist as they were presented to them by texts, instruments, descriptions of experimental procedures or pictures. This part of the discussion leads over to the discussion of more general aspects of science. General and guiding questions focus the NOS like "How do scientist generate new knowledge?", "How do scientists work?" or "How do scientists achieve success in their field?" The students discuss their general answers to the focus questions with a strong relation to the case study at issue. The teacher's task is to moderate the discussion and to cluster the ideas of the students on cards, at the blackboard or with similar devices. The last step aims at a generalisation of the students' answers, while the teacher asks them for further manifestations of their generalized "ideas about science". If the students for instance will generalize the idea of conflict among scientist, the teacher would ask them, if controversies currently characterize science as well. The teacher furthermore encourages his students to give a wide range of examples of conflicts and arguments among scientists.

This method 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 e. a., 2003). The internal structure of the reflection corner guides students' abstraction and provides opportunities to connect (and delineate) classroom context with that of authentic science.

Role play activities

Role play activities in educational settings 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 their lessons' content, if they are actively engaged in its representation. They will show a greater responsibility for their own learning processes. One may structure the use of role play in science classrooms by the categories of analogical, metaphorical and simulating activities (McSharry, & Jones, 2000).

Students engaged in analogical activities may take the role – in this case a relevant selection of physical properties mapped onto physiological or social elements – of physical entities like atomic particles or fields. This method is more common in younger children's science education at primary school. Its characteristics may be used to explore the role of models in science. Within an HPS approach it may serve to present the changing nature of modelling phenomena through history, for example the differences between a fluid- and particle-based modelling of electricity.

Metaphorical activities require a re-conceptualisation of known properties, events, situations or relations in a different context, where they have to be expressed as "standing-for" known things. Students need to analyze and evaluate a situation very thoroughly for example to create a human sculpture portraying all relevant aspects of this situation. Relating to HPS the students may mime for themselves or (collaboratively) sculpture a schoolfellow allegorizing a past scientist. He may just have trouble with anomalous data or be preparing for an important presentation. Social situations involving more than one scientist like arguments or collegueship are possible, too. This method is a powerful tool to visualize attitudes, emotions and social interactions in science, conveying elements its human nature.

Students experimenting in science classrooms are not per se simulating science. As stated above, this may hinder them from experiencing their activities as "scientific" even in an inquiry setting and so preventing them from meaningful reflection on the nature of science. Simulating scientific activities within an HPS approach should not be limited to historically guided inquiries, but also embed students' activities in contexts like research-groups, conference presentations, panel discussions, reviews etc. This will expand their notions of scientific activities and guide their future experiences. The simulation of controversies in science via these suggested settings is commonly advocated (i.e. Bell & Linn, 2002, Niaz & Rodriguez, 2002).

Role play activities in general emphasize the human side of science by re-creating integral parts of its social and emotional dimension within the classroom. Within these

settings students can practice taking roles and argument from different perspectives representing different value systems. Re-enacting social situations of authentic science in role-play settings falls back on students' basic experiential knowledge the gained within similar, real-life situations. Integrating and transferring this knowledge to the realm of science is a major goal that role play tries to reach within the context of school science.

4. A Symbiotic Strategy for Developing Case Studies

Even though science teachers generally appreciate the relevance of history and philosophy for providing a context for scientific knowledge, they feel unsafe about its inclusion for teaching about the procedural realm of science (Wang, 1998). Moreover, a lack of appropriate material for teaching and learning on all levels of school science education has been indentified (eg. Monk & Osborne, 1998, Höttecke, in print). An important quality of materials to be developed will be their appropriateness from a science teachers' perspective. Otherwise we should not expect a significant number of teachers making any use of them. On the other hand quality aspects from an academic point of view also have to be taken into account seriously.

The developmental model chosen for the HIPST project integrates the perspectives and capacities of researchers as well as science teachers from the very beginning. This mixture of expertise allows for the integration of several fields of expertise and knowledge. The model ensures a high degree of appropriateness of the material developed from the perspective of several academic disciplines involved in the project like history of science, philosophy of science as well as physics, pedagogy or developmental psychology. Next to these disciplines the teachers also provide important resources to the developmental process. They articulate their needs and wishes and predefine the scientific content they have to teach. Moreover, they contribute to the project with their didactical knowledge, creativity, their wide experience of teaching and opportunities for classroom evaluations of the materials. For a conclusive account of this symbiotic strategy see Höttecke & Rieß (in this proceedings).

The Thematic Working Group in Germany

Our thematic working group comprises 5 in-service teachers, 3 researchers (the authors of this paper) and an expert for the replication of scientific apparatus of the past.. Next to this core-group several additional teachers participate in the developmental process as advisors or provide opportunities for classroom evaluations of the materials developed by the thematic working group. All of the teachers involved are characterized by a high degree of affinity to HPS. Even though most of them do not contribute any teaching experience directly related to HPS, they almost all have collected extensive experience with HPS during their own professional training at the University of Oldenburg (Riess, 2000). Hence, they are roughly acquainted with the justification of teaching and learning with HPS, the integration of NOS aspects into science teaching and the use of replicas of scientific apparatus of the past as learning devices. While the group was constituted their professional development nevertheless did not comprise any detailed knowledge about skills and methods of teaching in these field.

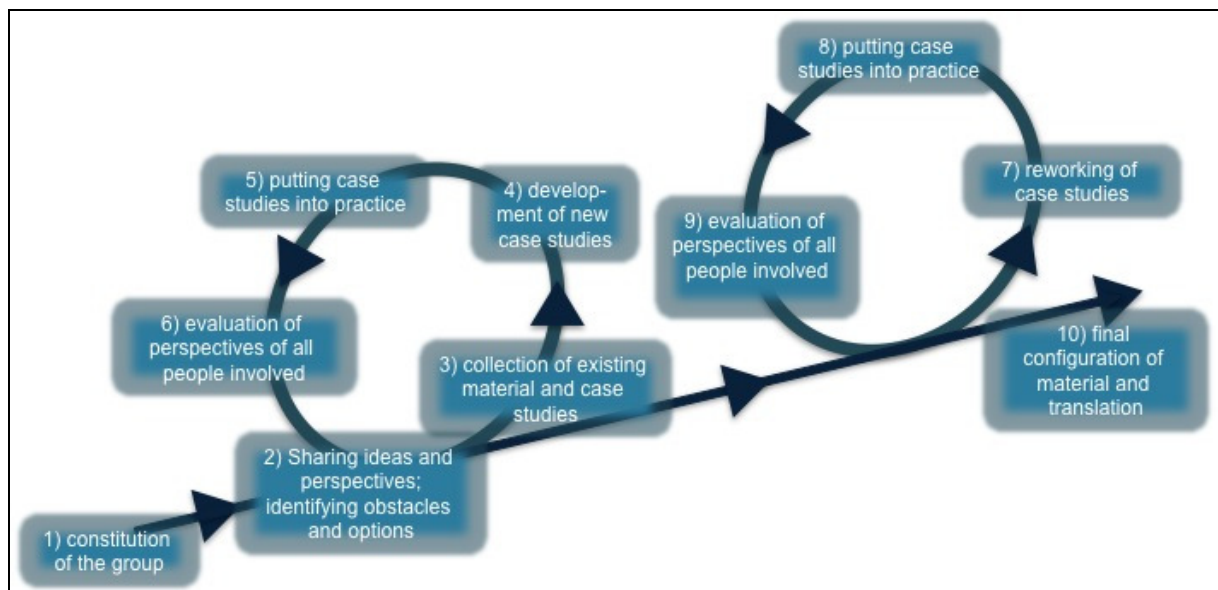


Figure 1: Developmental Model of HIPST

Structuring the development process

Researchers and teachers meet within a thematic working group regularly about once a month. Together they work on the development of case studies according to the overall developmental model (Figure 1, for a detailed account see Höttecke & Riess in these proceedings). It is hardly surprising that the developmental model does not represent a strict chronological order of steps. Instead usually the development process is

characterized by back and forth movements, which are caused for instance by the need for further professional development of the teachers, unexpected changes in teachers' schedules and curricula, new ideas regarding the storyline of the case study or methods of teaching and learning newly taken into account. A reconfirmation of perspectives, the reorganization of plans and the change of planned activities may also be due to teachers' critique or articulated doubts and worries on the course of the developmental process.

The steps 2 – 4 of the model focus on four key issues, which have to be negotiated among the members of the group.

Issue One - Gathering Options and Restrictions

Scientific content related to official curricula, personal preferences and fields of expertise of the teachers provide a starting point. Members of the group agree on the age range of the students and curricular topics as limiting factors of decisions on the next steps. Usually this process gives rise to an agreement on a small number of areas on which the future development activity will concentrate. Teachers in our group for instance decided against working on optics, because optics has been dropped from current curricula after the last reform in Lower-Saxony. It is not an obligatory topic for teaching physics in lower secondary schools anymore. The history of electricity instead was highly appreciated by the teachers, because it comprises subject matter they have to teach on several levels anyway.

Issue Two - Exploration, Immersion and Storyline

Teachers and researchers collaboratively are collecting available material like pre-existing case studies, HPS-oriented lesson plans, journal articles or available replications of historical apparatus. Furthermore, researchers in the group (the authors of this paper) present a concise history of ideas to the teachers spanning the conceptual domain the teachers have decided for. Information on the social, political, cultural and economic background is highlighted. Relevant preconceptions of students concerning the scientific content are discussed. Additionally evolutionary or revolutionary transitions of the historical development of ideas and theories are considered as well as anecdotes, controversies and blind alleys of scientific practice. We take into account accepted as well as rejected experiments and theories, since both are regarded as productive for learning science and about the NOS (Heering, 2003). The historical

resources comprise biographical material, illustrations. This procedure of immersion in the historical context provides a basis for the identification of central ideas and concepts to be learned. A preliminary storyline results, which is organized episodically and encompasses central concepts and ideas.

Issue Three - Discussion and Didactical Structuring

Physics teachers like other teachers usually plan and teach their lessons under a high pressure. Disparity of goals and practices is a consequence (Fischler, 2000). The main instructional orientation has to meet keeping the schedule, structuring the lesson along activities, and teaching content for future assessment. Since these orientations are deeply rooted in teachers' everyday routines and practices they have to be accepted as constraints of the developmental process as well as for the future use of the case study developed by the HIPST project. Within the group teachers and researchers raise ideas about didactical structures, which are negotiated among the partners until agreement is reached. We follow the basic idea of the model of didactical reconstruction (Kattmann, Duit & Gropengießer, 1998), which stresses a balanced approach of didactical structuring. Equal attention is paid to students' and scientific conceptions. Clear ideas on this relation guide the instructional use of historical material. (Liu, 2007).

Discussions in the group focus on four levels we consider as essential: the storyline, basic scientific concepts, the nature of science and the level of didactical considerations. All of these four levels are subject of discussion among the members of the group.

The level of **story line** means an episodic representation of relevant historical information along a narrative about science and its development. Major ideas, scientific concepts and problems of the topic are generated by the historical context (Stinner e. a., 2003). The story line ensures that single episodes are connected with each other. During the group sessions content and structure of the story line are subject to discussions and changes. Constant attention is paid on avoiding a whiggish approach to the history of science (e.g. Allchin, 2004). An interpretation of the history in terms of present scientific concepts has to be avoided in order to prevent a distorted view on the history of science. The level of story line represents the **historical-narrative perspective** on the developmental process.

The level of **basic concepts** describes elements of scientific content the teachers are planning to teach via the story line. The ideas and concepts of science are adopted as

content goals for the relating episodes. The level of basic concepts represents the **science perspective** on the developmental process.

The level of **NOS aspects** point out ideas about science and scientific processes, which are deemed relevant and accessible to students at issue. The level of NOS aspects represents an **epistemological perspective** on the developmental process.

The level of **didactical aspects** includes general pedagogical orientations and strategies as well as methods and media for teaching and learning like those presented above. Special attention is paid for the enhancement of conceptual change. The level of didactical aspects represents an **educational perspective** on the developmental process.

The multiplicity of levels and perspectives taken into account during the developmental process ensures a high quality, applicability and acceptance of the case studies.

Issue Four - Professional Development of Teachers

As Höttecke & Rieß (in these proceedings) pointed out although the German HIPST group comprises a subset of HPS-affine teachers, they are not necessarily familiar with innovative and student centred methods for teaching and learning. The more learning activities shift from closeness to openness, the more teaching strategies shift from being teacher-centred to being student-centred and the more instructional designs shift from focusing on content to focusing on context, the more science teachers feel unsafe and ask for further professional development. Since physics teachers' beliefs about teaching, learning and classroom organization are rather traditional (Markic, Valanides & Eilks, 2006, Willems, 2007), they usually are reluctant to employ open-ended activities and discussions in their classrooms and are hardly familiar with the guidance of role-play activities. Moreover, they often lack an adequate level of epistemological understanding. The latter is an important obstruction of teaching adequately about the NOS. Furthermore, teachers are in danger to re-interpret the history and nature of science according to their own problematic conceptions in this field (Abd-El-Khalick & Lederman, 2000). As a consequence the professional development of teachers involved in the group has to be promoted. Therefore, teachers' understandings of the NOS as well as their didactical skills have to be conveyed, in order to reach ownership about didactical means and strategies integral for teaching the case studies developed in the HIPST project.

Professional development is reached on several levels: On the one hand the researchers in the thematic working group offer further training for the acquisition of relevant knowledge, concepts and teaching skills. For example role play activities are collaboratively simulated or experiments are explored during hands-on activities with replicated instruments. On the other hand the experiences made by the teachers during their own teaching of the case studies are reflected within the group and lead to further professional development of all people involved.

5. Cases Studies

During the first 15 months of the HIPST project the German thematic working group has developed four extended case studies according to the developmental model and basic ideas described above:

- History of refrigeration technology: An exploration of the interplay of science, technology and culture (grade 5)
- Moving bodies: A case study for the enhancement of conceptual understanding of mechanics (grades 7-8)
- Early history of electricity in the 17th and 18th century: multiple case study about the interplay of science and culture and the social dynamics of science (grades 8-10)
- Galileo's pendulum: students explore the laws of the pendulum and the general role of experiments in science (grades 8-10)

In the following chapters the case studies will be described in brief.

History of refrigeration technology

The first case study aims at the exploration of the interplay of science, technology and culture in the context of development and application of refrigeration technologies. It is directed to students aged 11 to 12. Small groups of students are working and learning at thematic centres. Each centre offers historical information and accompanying tasks for the students. Among them are creative writing and inquiry activities related to the historical context at issue. According to the wishes of a teacher of the German thematic working group called Tina the case study has to meet the curricular goals the science

teachers at her school have agreed on. Among them are "technical instruments in everyday life" and "basic ideas of thermodynamics". The latter comprises aggregate states of matter, phase-transitions, heat conduction and isolation. She justified the method of thematic centres she had chosen with her long experience with it and positive effects on motivation and autonomy of her students. Additionally she stressed general benefits for classroom organization. The students are for instance allowed to move back and forth between several thematic centres according to their wishes and decisions. They were moreover free to decide for re-doing an experiment, if they will feel unsatisfied with their previous results.

The case study is organized along thematic centres. Since the students are not obliged to follow a stipulated sequence of thematic centres, "rush hours" at each of the stations are avoided. Just one centre is obligatory. The students work together collaboratively in five small groups. Since the number of groups is restricted, the teacher is able to offer an appropriate amount of time per group for scaffolding their learning and problem solving by asking and answering questions, by providing additional information or by giving practical advice. This may reduce trial-and-error strategies or frustration if the students are not familiar with open-ended activities. The students' marginal knowledge of and abilities to do inquiry-type activities, their naïve views about scientific research and weak epistemological understanding led to very basic activities at the thematic centres. "Asking questions" or "making assumptions" are examples among others.

At the first thematic centre a list of events about the history of refrigeration technology will be presented to the students. They are neither occurring in a chronological order nor do they lead straightforward to the present state of technology. Instead, they are supposed to highlight and exemplify technological innovations as a driving force of science. The students are asked for their own ideas about goals and intentions people in the past might have had for developing technologies like domestic iceboxes or freezing-mixtures for icing milk or cream. During the next step the students are asked for writing about a life without our current refrigerating technologies. They for instance imagine how an early hunter or fisher might have stored and preserved his food. Since many students have somewhat simplistic views of the motives and backgrounds of research activities (Schwartz e. a. 2008) they may be surprised by such basic needs providing the background for the progress of refrigeration technology. The last activity will be the

realisation of as many as possible of their written ideas of cooling things within the classroom with a wide range of materials being available.

At the second thematic centre students will explore the effect of cooling by evaporation of liquids and its use throughout the cultural history all over the world, for example the laborious mass production of ice in the British colonies in India via small fictile bowls in cool nights. In an inquiry activity the students try to answer the questions of different liquids cooling down with different velocities and how the area of evaporation affects this velocity.

At the third thematic centre they face a modern story of Bah Abba, a Nigerian teacher and previous potter who could support the rural subsistence farmers with a cheap method of cooling by evaporation. In this context they are asked to identify the reasons and previous knowledge that are intertwined in the process of developing this device. In the phase where the students present their results there will be much discussion - if on the one hand the dire need for storing fruits to be sold and on the other the scientific education of Bah Abba were necessary or sufficient factors especially in this process or for science & technology in general. In an inquiry activity the students try to answer the questions of how moving air may influence the temperature inside the device. Also a commonly held conception of science being "inventing stuff" may be assessed and discussed by contrasting Bah Abba's invention with the students' own actions during the inquiry activity (i.e. working on a research question, making hypotheses, collecting data etc.).

At the fourth thematic centre the quest for artificial refrigeration provides the context for learning the concept of the boiling point of fluids. It has long been recognized, that children have some special preconceived ideas about boiling (i.e. being a process only possible at high temperatures) which impede their understanding of the Linde-Process - at work in nearly every standard refrigerator. To open up the way towards characterizing materials by their boiling point first the relational nature of this measure is made clear by imagining hyperthermic creatures, who would be injured by the coldness of boiling water, and the analogy to humans handling liquid nitrogen. Before, they will have experienced and measured the stability of boiling points on heated water. Research on methods of artificial refrigeration provides the starting point for reflecting the multiplicity of factors influencing research and providing possible motives - like the need for continuous and lightweight cooling on cargo ships or the now cheaply available

beet sugar removing ice-cream from the luxury list were it not for the massive amounts of ice and salt needed.

The second part of this centre integrates the ideas of boiling, evaporation and cooling in a schematic overview of the linde-process at work. The changes in the coolants at work will be discussed in the light of scientists being responsible for damage to people or the environment caused by technologies buildt on scientific research.

At the fifth thematic centre the students face the concept of insulation in the context of a problem like how to keep ice cubes from melting. They will use their insights from an inquiry activity to write a short introductory chapter to a book presenting the latest advances in insulation and their application in building ice-houses. They are then asked to reflect on differences and similarities between the domains of science and technology.

At the sixth thematic centre the widespread use of in-home ice-boxes until the late 1940s provides a context for learning about the upward/downward motion of hot/cold air. They re-examine the elaborate implementation of this principle in these boxes.

At the seventh thematic centre freezing mixtures shall be explored. This is done in an irritating manner, using the students' previous knowledge about the winter service using salt to melt snow and ice. They are faced with the plausible hypothesis of salt-ice mixtures warming up beyond the melting point of ice. The following inquiry will lead them to a dismissal of that hypothesis followed by reflecting on how scientists may react in such situations. They will be faced with another problem of how to optimize the use of salt in freezing mixtures, since in some regions the use of freezing mixture was limited by the availability and price of raw salt or salpeter.

At the eighth, ninth and tenth thematic centres the students will explore the multicultural and discontinuous history of ice-cream. In this context they may overcome typical preconceptions of scientists' tasks like producing phenomena or inventing things by explicitly differentiating between the widespread use of freezing mixtures for producing ice-cream and the scientific investigation of the underlying effect nearly 100 years later in 1635.

This case study provides an elaborate example for teaching which explores the intimate relationship between science, technology and society while still including learning opportunities for basic scientific concepts via student centred methods.

Moving bodies - from Aristotle to Galilei

The next case was motivated by a teacher with significant knowledge about Galileo's astronomical research. He regularly enriches his lessons with historical anecdotes and arranges after-school astronomy projects in this fashion. He was keen to integrate Galileo's research on the movement of bodies in the curricular framework of kinematics in the ninth grade. It was soon established that another critical issue would be the consideration of students' preconceptions about motion, force, inertia and acceleration, which would be the main concepts to develop during the instructional unit. The teacher is familiar with the idea that many of these preconceived notions can be understood as generalisations of everyday observations which – in a somewhat broad sense – parallel that of early natural philosophers. Taking all that into consideration we decided in favour of a story-line centering on the changing ideas about motion and its investigation – taking the big leap from Aristotle to Galileo as an example. To guide the whole course of the unit we followed a suggestion by the teacher and devised a fictive dialogue between Aristotle and Galileo. In it these two argue about the main ideas of each episode of the unit. By staged reading of the dialogue the students get the historical information in a motivating way and are able to take the main characters' perspectives. The ideas about science which are embedded in the dialogue provide the background for subsequent reflections on the nature of science.

The students start with a seemingly straightforward task of categorizing a set of images of everyday objects being in different states of motion. Producing knowledge by observing and categorizing one's observations is highlighted as one method of inquiry while the multiplicity of resulting schemes may be a starting point to discuss the influence of one's own background knowledge on interpreting data. The first part of the dialogue introduces the two main characters while putting the most emphasis on Aristotle. He presents a condensed version of his views on the task of science and his resulting categories of motion in relation to the final cause of every terrestrial object. He also presents his reasons for the heavenly motions being a somewhat different affair. Together the class now tries to follow Aristotle's scheme and discusses the plausibility of it in the light of his philosophical worldview. Other examples of categorizations in science and their basic goals are discussed.

Due to time restrictions the teacher did not consider an explicit discussion of other aspects of what we now reconstruct as "Aristotelian dynamics". He wished for a clear,

but meaningful separation of Aristotelian physics in distinction to the ideas of Galileo. For that reason, the next episode starts with the characters arguing about their differing views on goals and methods of science highlighting the idea of scientific knowledge as well as the methods of science being subject to change.

The next episode combines the concept of inertia with a procedural approach to the method of idealisation in science. The dialogue therefore includes the widely known thought-experiment of an ideal inclined plane. In this context the students are requested to perform an egg-race about maximizing the distance of balls rolling down an inclined plane. The students are free to choose inclination and materials while the height at the starting point is fixed. Afterwards they hypothesize about ideal conditions of their set-ups. The usefulness of idealisation in science is then a point of discussion between Aristotle and Galileo. This arrangement of student activities is based on research findings about students' misconceptions about idealisation being motivated by the diffuse desire to improve something mechanically. The deliberate use of this method as a cognitive tool in the context of scientific research therefore has to be explicitly addressed.

For the second part of the unit we chose the context of an after-school project comprising several stations. The single stations may also be implemented as normal lessons. In this part the students work in small groups on a single project and afterwards present their results to the class. Every project includes staged reading of a part of the dialogue.

In the first project about the free fall of bodies the students contrast an Aristotelian view of the fall of bodies, which includes the impossibility of frictionless movement, with the bold Galilean proposal of an eternal movement at constant speed. Alongside, the dialogue critically discusses the method of thought experimenting including the known experiment on the logical impossibility of mass-dependent terminal velocity. The students may present the modern "feather vs. lead-ball" experiment to the class during their presentation.

In the second project they may work with a portable replication of the inclined plane retracing Galileo's steps towards a mathematization of accelerated motion independent from the plane's inclination. Again, the role of idealisation in connection with real world experiments is reflected – where some variables are defined as essential and others as disturbance, a point taken up in the fictitious dialogue as well. It is pointed out that

mathematical descriptions may only be connected to real world processes via conscious idealisation.

In the third project the students explore the different consequences of an Aristotelian system of explaining motions versus a Galilean one. In the first case there have to be two separate systems of physical laws, one governing the earth and another describing heavenly motions. Idealisation and inertia provide the ground for a unification of these systems. The students stray a bit from the original topic of dynamics when observing and sketching the surface of the moon (either real or projected to scale) using replications of the famous Galileo telescope. This activity provides the observations used as evidence against the special They are also asked to reflect on the significance and justifiability of their and Galileo's results concerning the difficulties of observation.

Early History of Electricity

This instructional unit was the first being developed, since it was highly appreciated by the teachers and there were pre-existing materials outlining a historical-genetical approach (Misgeld e. a. , 2000) to the conceptual development from early electrostatic attraction to the construction of leyden jars (the main source still being Heilbron, 1999). It has a very clear cut episodic structure featuring the historical contexts of discovery of basic concepts like electrostatic attraction & repulsion, conduction of electricity or electric circuits.

In the first episode an inquiry activity will be motivated by the fictive lab-diary of William Gilbert - which unfortunately has many missing passages the students are asked to reconstruct. The structure of this diary and the available help cards provide different levels of guidance during their inquiry. The overall question will be how (and if) to distinguish between the attractive effects of magnets and electrics. Materials provided will include a replication of Gilbert's versorium. The explicit reflection will be twofold, on the one hand specific questioning highlighting the personal and cultural influences on science and scientists and their use of previous knowledge and on the other hand an interview with William Gilbert through a creative writing task which focuses on methodological aspects of his work (exploration, discrimination of phenomena).

In the second episode the students deal with Otto von Guericke's experiments on electrostatic repulsion (and attraction) using replications of his sulphur globe. The research is motivated by Guericke's desire to explain the world by a simple set of forces

governing all phenomena analogous to those shown by electricity. The students reiterate his results on attraction and have to devise an investigation to account for repulsion. A first stage of reflection may target gains and risks in the use of analogies and similarities in science (extra-rational shaping principles). To start the second part of this episode the students are confronted with the Royal Society's scepticism towards Guericke's instrument and discuss the role and possible quality criteria for scientific instruments. Teachers' reports on the motivating effects of students inventing scientific instruments induced us to put the students in the role of an instrument maker designing an electrifying apparatus to fit the criteria developed before. They may then compose a short advertisement going along with their drawing pointing out the quality features of their instrument. In our view these activities are able to convey a realistic view of scientists' use of instruments in the context of justification on the one hand and their dependence on being supplied with high quality instruments on the other.

The third episode is based on Charles François de Cisternay du Fay's research on the dual nature of electricity and provides some opportunities to reflect on the nature of and theories and laws and their differences. Whereas his theory of two electricities creatively explains his observations, he also sets up a rule (or law) describing charge-exchange processes. Basic scientific concepts include transferability and conservation of charge and of course the need for two kinds of charges to account for the observed phenomena.

In the fourth episode they will encounter Stephen Gray and explore the ideas of electrical conduction, especially the difference between conductors and isolators. They will follow along the evolution of his instruments until they face the question of what makes an object conduct electricity – a material quality or a special form? Guided by his hypotheses and observations they may arrive at his (blind alley) conclusion of conductivity being solely dependant on the materials' thickness. Just by coincidence and collaborating with a colleague he (and the students) may prove himself wrong. For the students this will give rise to discussions about the tentativeness of scientific knowledge (what if he had not put it "right"?) and a view of scientific instruments evolving with time and hypotheses.

The fifth episode portrays a "clash of cultures" between itinerant lecturers and other practitioners in the field of electricity. The students are introduced into the exemplary case of physics professor Georg Christoph Lichtenberg agitating against the itinerant

lecturer Martin Berschitz. The framework being motivating demonstration experiments from this era on another level the students discuss and criticise the different ways scientists try to confine themselves via review systems and assigning special character traits to scientists and non-scientists. The students may explore the non-rational elements of this process via constructing human sculptures of Lichtenberg and Berschitz. They will integrate all the information in imagining a typical situation and sculpturing facial expressions, gestures and scenery accordingly.

The *sixth and last episode* deals with the concept of the electrical circuit, deepening the understanding of the conservation of charge but also opening up ways to define voltage either from charge difference or from work done on unit charges. Before that, the students will play their roles as supporters of a model of electricity consisting of either one or two electrical fluids proposed by Franklin and Symmer, respectively. They present their model and its usefulness in explaining the inner workings of the Leyden jar in the context of a conference organized by Lichtenberg. Having students experience both ideas about charges has its merits, since Franklins conceptualization goes well with the idea of potential whereas Symmers model carries over to the particle model of electricity. Also, a discussion about the pros and cons of each model may be reflected on a metaconceptual level in the sense of pragmatic modelling as a typical scientific activity. This way the students may overcome the need for the ultimate right answer to this controversy in favour of a “working solution”, which in fact is what Lichtenberg will propose to them in this situation. This will provide a bridge to a modern model of electricity.

Galileo’s Pendulum

This case was initially developed and evaluated within the scope of a master’s thesis at the University of Oldenburg. The students will explore the five theorems about pendulum motion in an elaborated context, which provides much information for a subsequent reflection on the nature of science and scientific methods. Therefore, each of five groups of students will receive a short correspondence between Galileo and his patron Guidobaldo del Monte, the former repudiating the latter’s Aristotelian criticism on his methods used to derive the theorem in question. Reflection will take place in a dramatized setting, where students stand side-by-side with life-sized drawings of Galileo

and del Monte. They take these roles for commenting on how science has to be done, relating on the correspondence as well as their own experimental experience.

Conclusions

When collaborating with in-service teachers one more than once faces the hurdles of practice but on the other hand is awarded with the teachers' sweeping enthusiasm. We all learned (and still learn) a lot from this experience. On the more practical side we realized, that developing several case studies in parallel within one thematic working group is counterproductive when done solely in the group sessions. The rather long intervals between group sessions seem to demand *one* central "construction site" spanning a couple of sessions for all participants to get immersed in reconstructing the case und designing the relating lessons. This puts additional constraints on the amount of preparatory work that can be done by us, since teachers cannot perfectly plan ahead their topics of teaching for several months.

We also learned a lot about the amount of scaffolding teachers need when implementing historical case studies. This has to be provided by the teaching material, including manuals on proposed teaching methods like role-play, inquiry activities, discussions or historical replications. Also students' tasks and worksheets as well as examples on how to motivate and guide inquiries (without prescribing them) will be useful as well as concise descriptions of content and nature of science learning goals, the latter needing legitimating from the teachers' perspective.

For example, the teachers whom we are working with, do not seem hold specifically naive views about the nature or philosophy of science, instead they mostly seem non-expressible und undeveloped. When prompted in the context of HPS they arrive at very plausible and in many ways realistic ideas about science. We learn that teacher education should employ a more structured preparation of student teachers in the field of HPS and strengthen the use of the "nature of science – lens" throughout their studies. Otherwise, one cannot expect teachers to explicitly address these topics in their classrooms or even recognize them when designing HPS-informed lessons.

During the process of emergence and delineation of distinct NOS issues in the development work, the teachers expressed their dire need for a rationale for selecting and *integrating* elements of the nature of science in their teaching. This highlights the need for teacher education to convey criteria for relevance (as proposed in Lederman,

2004) and along with it knowledge about different procedures, methods and rationales to realize HPS with NOS in the classroom. HPS as content in teacher education is just one first step towards implementation in school practice. One may infer this by the observation that most of the collaborating teachers did indeed include HPS intuitively in their teaching, but without knowing there were dedicated methods to do it. Empirically founded pedagogical knowledge and strategies allowing that inclusion are mostly neglected in their education until now.

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