

Historical Approaches in German Science Education

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Particularly in the second half of the 20th century, historical approaches became relevant in science education. This development can at least in part be explained with the growing awareness of the importance to address Nature of Science aspects in science education. In comparison to the international publications, some particularities can be identified in Germany. Most notably, using historical approaches is mainly limited to the field of physics education, only few approaches can be found in chemistry and hardly any in biology education. Moreover, several approaches have been realized which use historical experiments in educational settings. This paper gives an overall analysis the historical approaches and their role in German science education as well as some insights into current approaches.

Keywords: history of science, nature of science, science as culture, storytelling in science education, historical experiments

INTRODUCTION

History of science (HoS) has become a particular approach in science education worldwide, particularly since the 1980s. This is certainly not the place to discuss the whole development of science education curricula in detail, it may suffice to indicate that particularly during and after the Cold War, new paths of teaching science were to be developed in many countries of the world. Reasons for implementing historical aspects into science education have been made explicit e.g. by Matthews: “History, philosophy, and sociology of science ... can humanise the sciences and make them more connected with personal, ethical, cultural, and political concerns ... (Matthews, 1992, 11). These arguments are also nowadays central in the justification of historical approaches in science education.

However, there are two more arguments that can be found: It has been argued that historical approaches are

particularly useful for teaching the Nature of Science (NoS). Moreover, there are also some indications that historical concepts may correspond to those developed by young students and that can be labelled as pre-concepts – thus an historical approach may enable students to understand why their conceptual understanding needs modification without making their concept void. A variety of publications (e.g. Allchin, 2013; Bevilacqua et al., 2001; Matthews, 1994; Matthews, 2000) demonstrate the broadness of the existing historical approaches. However, it has to be understood that any historical approach is not advocated as a sole approach in science education, on the contrary most authors emphasize that HoS may be a useful and enriching expansion of the established ways of science education.

In this respect, it is important to realize that we have not only claims in this respect but also some empirical evidence: several studies indicate that using historical approaches are not only helpful to students with respect to developing a better understanding of scientific content, but also “help to achieve a better understanding of the essence of scientific phenomena, scientific methodology, and overall scientific thinking” (Mamluk-Naaman, Ben-Zvi, Hofstein, Menis, & Erduran, 2005, 501; see also Galili & Hazan, 2001; Hadzigeorgiou et al., 2012; Heering, 2000; Irwin, 2000).

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State of the literature

- History of science is considered to be one manner on how to get topics from the Nature of Science into the classroom.
- Quite a number of case studies on using the history of science in educational contexts exist.
- Contrary to other regions, a coherent description and analysis of the respective approaches in German science education does not exist.

Contribution of this paper to the literature

- The paper provides an overview of the recent approaches in implementing history of science in educational contexts in Germany.
- At the same time, the peculiarities of the German approaches compared with the international situation are highlighted.
- This paper provides a meta-perspective of the German approaches in implementing the history of science in science education.

These studies have in common that historical episodes were not just used as small vignettes (as suggested e.g. by McComas, 2008) but the historical context provided a structure throughout the lesson(s). Whilst vignettes may illustrate certain aspects from NoS, using a historical context as a structuring element in educational processes appears to have more potential with respect to combining the gain of competences of learners both on the content and the NoS level. Yet, as Allchin (2004) has pointed out explicitly, one has to be cautious not to use pseudohistory: history that is simplified or modified in order to meet some ideals about how science should have proceeded. Likewise, the problem of whiggishness in the historical narrative is particularly present in school textbooks (Höttecke & Silva, 2011).

Recently, several studies analyzed the use of HoS in science education on a regional level (e.g. for Argentina, Brazil, England or Mexico will be published in Matthews, 2014). A respective review for Germany does not exist so far.¹ In order to meet this desideratum, the development and current state of historical approaches in German science education shall be discussed in this paper. In the first part of this paper, the initial development towards establishing historical approaches in German science education will be sketched. In the following sections, the respective situation and some recent developments in the fields of German science education in general and in physics biology, and chemistry education in particular will be discussed.

¹ When speaking of Germany, it is useful to implement also the works of science educators from Switzerland and Austria. However, I will not discuss the implications for their respective educational systems as these differ significantly from the German one.

The History of Science in German science education – Historical development

There is a long tradition in Germany with respect to analyzing the HoS, and one motive for doing so was suggested in its educational potential. However, despite such influential works as Poggendorff's (1879) or Rosenberger's (1882) monographs on the HoS, there was no systematic approach to use the HoS for educational purposes for quite a long time. Probably the first scholar in the German context to make an explicit approach in using HoS for educational purposes was Ernst Mach (1912, on Mach's work with respect to science education see in particular Siemsen 2014). Apart from the axiomatic and the socratic approach, Mach encouraged an historical approach in order to focus on epistemological issues as well as to enable the student to develop her or his own understanding instead of being confronted with mere facts (Siemsen, 2014).

Mach's approach remained exceptional throughout the 20th century. Nevertheless, his work probably influenced several German science educators, foremost Martin Wagenschein who became a central figure in the German science (physics and mathematics, to be more accurate) education in the 1950ies and 1960ies. Wagenschein (1968) addressed – apart from his emphasis of the exemplary and the socratic aspects he advocated in educational processes – an approach he characterized with the term genetic, however, his understanding of genetic was associated with the individual child and not with the discipline.

One of the critics on Wagenschein was suggested by Jens Pukies, a member of the Oberstufenkolleg Bielefeld. Pukies and his colleagues aimed at developing an alternative approach in science education that contains a significant political component – science was to be understood as part of a political and also societal construct, and science per se is not free of values. Based on this understanding, Pukies in particular (1979), but also other authors such as Freise, Kremer, Ohly, and Rieß advocated a historical-genetic approach. In this approach the idea of “genetic” was no longer focusing on the individual's cognitive development as in Wagenschein's pedagogy, but addresses the genetic development of knowledge within the sciences – genetic in this sense is understood more of a collective than of an individual. This approach aimed at enabling the learners to understand not only the scientific content, but also to put science into a broader political, philosophical, societal and historical context. Parallel, and to some extent independently to this development, several other historical approaches started to develop. Clearly the most remarkable one in this respect was developed by Teichmann (1979) in physics education.

The state of the art in German physics education²

If one looks at approaches in using HoS in educational contexts in Germany it is evident that the field of physics education is absolutely dominant. However, even though the degree of dominance appears to be slightly lesser on the international level, it is striking that also on a general level the majority of educational materials on HoS come from the field of physics education. Thus, the approaches to use historical approaches in German physics education appears to be somewhat corresponding to the international situation, the peculiarities seemingly lie more in the fields of biology and chemistry. However, a closer look reveals that there are also peculiarities in physics education, not on a quantitative level though, but on a methodological one.

Several scholars developed or adopted a methodological approach that uses re-enacted historical experiment as means for education. Such a methodology has already been proposed outside of Germany (Devons & Hartmann, 1970; Devons, 1987; Hartmann Hoddeson, 1971; Kipnis, 1989, Kipnis, 1993). For a detailed discussion of these approaches on the international level see (Heering & Höttecke, 2014). In Germany, such an approach has been applied various times, Achilles (1996) and Wilke (1998) both fostered an approach that re-enacted the working principle of classical experiments from the history of physics. However, they limited their work to bringing together some discussion on how the reconstructed device can be realized and gave just a brief historical contextualization. Teichmann additionally carried out historical research and thus developed a somewhat broader picture (Teichmann, 1999; see also Teichmann, 1979), however, also in his work, the material aspects of the experiments were not an issue.

A more sophisticated approach had been developed at the Oldenburg group led by Falk Rieß. In the so-called replication method, historical instruments were reconstructed according to the source information, the experiments were redone and the respective experiences were historically contextualized. The instruments, together with the findings, were implemented in educational settings, mostly on university level (Rieß, 1995; Rieß, 2000; Sichau, 2000; Heering, 2003), but also in school setting (for experiences in upper secondary school see Heering, 2000; for an approach aiming at lower secondary school level see Höttecke et al., 2012). This approach was also used in the HIPST-project which was funded by the EC and included the

collaboration of physics educators and physics teachers (Höttecke 2012, Höttecke et al. 2012). In these approaches, a central motivation lies in the fact that the scientific content that had been produced with the instruments is not yet hidden in the devices. As a result, the instruments have still an “intellectual transparency” – by this the behavior of the instrument can be questioned by the user, and that in the meaningful interaction with the instrument, its behavior can be understood. This is different with modern devices even if they have been designed for educational purposes (Rieß & Schulz 1994). An approach that is similar to the one used in Oldenburg has also been applied at the University of Jena (Frercks 2011). Besides the aspects that have been pointed out by Matthews, these approaches have in common that material and performative aspects of as well as cultural influences on experimental practices are amongst the competences that the students are enabled to develop. A significant problem with this approach appears to be the availability of the instruments: most schools do not have the opportunity to visit the respective university or to get instruments. In this respect, recently a modification had been undertaken where students were to build their own version of historical devices based on their examinations of instruments from university collections (Asmussen & Heering, 2014). Additionally, attempts were undertaken to use modern version of classical experiments together with a historically informed contextualization for educational purposes on university level (Heering & Klassen 2010).

However, despite the broadness of this particular approach in implementing HoS in science education, there are also other ideas in German science education: A fairly unique manner has been suggested by Barth (2000). He used excerpts from Faraday’s laboratory notes to teach electromagnetic induction to upper secondary students. Likewise, Panusch (2012) suggested using Millikan’s original data in teaching the elementary charge. Another fairly unique approach has been established by Grebe-Ellis and his colleagues. The so-called phenomenological approach includes the historical analysis of the field under discussion (Grebe-Ellis, 2005). Finally, there are several studies that relate the historical conceptual development with the pre-concepts of students at various levels (Liu, 2005; Osewold, 2007; Heinicke, 2012). Liu’s work is particularly remarkable in this respect as she compares the concepts of young children in Germany and Taiwan with the respective concepts that were developed in the HoS. Liu shows empirically remarkable parallels between the children’s concepts and the historical ones, thus making an argument for the culturally embeddedness of students’ preconceptions.

² In Germany, physics (like chemistry and biology) is only taught at the secondary school level. Historical approaches seem to play no role in primary school education.

The state of the art in German biology education

One can argue that there are hardly any approaches that use historical materials in German biology education. This is even more astonishing as on the international level there is a broad variety of historical case studies as well as stories that were designed for educational purposes in order to implement HoS in biology education. However, among the few exceptions one is particularly remarkable: Markert (2012) enabled students from a lower secondary school to make microscopic experiences that were linked to the work of the German botanist Schleiden. In analyzing their drawings and their difficulties, he was able to draw some parallels to the historical development. At the same time, his knowledge about the historical development instructed him in the preparation of this course. In another study, Markert (2013) demonstrated that German biology textbooks are not appropriate with respect to the HoS.

The state of the art in German chemistry education

Like in biology education, there are hardly any systematic approaches to implement HoS in German chemistry education. However, different to the field of biology education, this corresponds also to the situation on the international level. Even though there are some approaches to implement the HoS in chemistry education internationally (Chang, 2011; Eggen et al., 2012; De Berg, 2010; Niaz, 2000), this area is significantly underrepresented compared with the other areas of science education. However, there are also a few approaches in German chemistry education too. Jansen, clearly one of the most prominent scholars in the field of German chemistry education at the turn of the century, published together with his colleagues several papers in which he advocated the use of history of chemistry for chemistry education (Matuschek & Jansen, 1992). However, their approach uses the history of chemistry more as a stone pit. Moreover, his approach towards HoS has to be criticized as being alienated. Consequently, despite the fact that they use historical materials, the works of Jansen and his colleagues are not really dealing with learning through the HoS, even though they are to some extent representative for the state of the art concerning the use of the history of chemistry in educational settings at the end of the 20th century. Nevertheless, there appears to be some development, recently Cura has published some materials on using HoS in German chemistry education – in this respect she is clearly advanced. However, she is an individual exception, and her publications are just short case studies (Cura, 2011).

Current Developments: Case studies from the History of Science

On the international level, case studies were initially the dominant materials, starting with the ones put together by Conant (1957). Recently, we also find a substantial number of studies that propose science stories for educational purposes (Allchin, 2012; Clough, 2011; for a theoretical discussion of this approach see Klassen, 2010). This approach can be seen as the currently most relevant approach in applying historical materials in science education. Both approaches can also be identified in German science education. A series of historical case studies had been published by the Deutsches Museum Munich (e.g. Eckert & Schubert, 1986; Meya & Sibum, 1987; Osterroth, 1985). In Switzerland, Kubli (2005) proposed the use of stories in science education to German science educators – however, he did not put the emphasis on using historical materials in such an approach.

Currently, Heering and colleagues are involved in a project where science stories are used for educational purposes in lower secondary school education. In this project, the emphasis is placed on the actual telling of these stories, thus distinguishing this approach from others where the story can be read either by the teacher or by the students.³ In order to illustrate the potential as well as the broadness of historical approaches, this project shall be discussed in a broader manner: 18 historical case studies were transformed into educational items that include the story, historical as well as biographical backgrounds and educational materials. The topics for the case studies were chosen according to the content which needed to be relevant in the context of lower secondary school curricula – central topics to be used were the energy concept, nourishment, and the atomic model.

In order to show the educational potential, one of these stories shall be discussed in some more detail: James Prescott Joule and his work that is related to the establishment of the principle of energy conservation (Joule, 1850). Classically, one can develop a script as follows: The Manchester owner of a brewery developed in the mid-nineteenth century a device which transformed mechanical force (a term that was used for the entity we nowadays call mechanical energy) into heat. Falling weights stirred the axis of a paddle wheel that was inserted into water. The increase of the water's temperature was measured and served as an indication of the heat produced. Joule was able to demonstrate that mechanical force was transformed into an equivalent amount of heat, thus demonstrating that an entity was conserved – his empirical work served

³ Further information about this project can be found at <http://www.science-story-telling.eu> (Accessed 06.12. 2013).

(together with the more conceptual approaches of Julius Robert Mayer, Hermann von Helmholtz and William Thomson, see Kuhn (1959)) to the establishment of the principle of energy which is nowadays fundamental to science. Accounts such as this sketch can be found in a variety of textbooks, both at school and university level. However, despite the fact that some historical actors are mentioned and even a period is identified, this account would certainly not qualify as a historical one.

When looking closer at Joule's work, several aspects get evident which are useful for educational purposes.⁴ To begin with, Joule's set-up had to be used in the basement of his brewery – it was necessary to have a uniform room temperature which could be ensured by using a room with a huge heat capacity. Likewise, it was necessary to have someone who is doing the work – as Sibum (1995) pointed out, this was probably an unknown and – due to the social status – unmentioned brewing mate. However, the skills that were required from this unmentioned person are also crucial for the successful performance of the experiment. Additionally, it was necessary to have instruments that are sufficiently sensitive – Joule had access to some of the most sensitive thermometers which were made by Dancer, a Manchester instrument maker. Joule claimed that with these instruments, he could achieve a reading accuracy of 1/200°F. At this level of accuracy, temperatures are permanently fluctuating, thus it requires again skills in order to be able to carry out these measurements. Thus, it could be argued that internal factors such as material, instrumental and performative aspects were crucial for the success of the experiment. However, there were also other aspects involved, on the one hand, Joule had to have a conceptual belief in conservation as his first results cannot be taken as indications of a constant ratio between mechanical force and heat. Yet, he was over several years able to stabilize the performance of the experiment until he was finally able to produce data that correspond to the idea of a mechanical equivalent of heat. Moreover, even when he was able to come up with appropriate results, Joule still needed support of William Thomson (later Lord Kelvin) who was an influential figure in the British scientific community and supported the work of the outsider Joule.

Based on these historical aspects, it is possible to come up with stories that address different aspects with respect to the NoS. Here lies a major potential of such an approach, historical materials can be adapted to the intentions of the teacher in order to illustrate or motivate discussions of NoS aspects. Thus, content oriented materials, and even inquiry based-approaches

can be contextualized with the historically informed story that helps to come to a broader discussion of what science is about.

In the above mentioned project, most of the materials are addressing central concepts such as energy or the atomic model. However, at the same time these stories are related to the individual science subjects. Partly this is related to the structure of German science education at school and university level. Generally, German science education still addresses the separate subjects biology, chemistry, or physics. Even though teaching science classes instead of separate subjects is getting more important at least at school level, few approaches exist that may be considered as being addressing a holistic picture of the HoS in German science education.

CONCLUSION

Approaches to use HoS for educational purposes are currently in Germany almost entirely limited to the field of physics education. However, the growing role of science education (instead of the education in separate disciplines) may open also a path for broader approaches. However, it is evident that the approaches that were developed in German physics education strongly emphasize the role of practical work. In this respect, the interpretation of HoS for educational purposes in German physics education can also clearly be distinguished from the international ones.

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⁴ To develop a better understanding of the experimental procedures one may consult a video that shows the re-enactment of this experiment that had been carried out for educational purposes, see <http://youtube/MBrTDKc9YZ0> (Accessed 03.01. 2014).

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