**Towards a history and philosophy of scientific education in practice**

Pieter Present

Centrum voor Logica en Wetenschapsfilosofie, Vrije Universiteit Brussel

pieter.present@vub.ac.be

**Abstract**

Teaching is an important aspect of scientific practice. However, as Lorraine Daston has recently remarked, “we have only the barest beginnings of a history of scientific pedagogy and not even the rudiments of a philosophy” (Daston 2008, 106). Daston refers to some historical studies on scientific education, including the collection of studies edited by David Kaiser (Kaiser 2005). In the concluding chapter, Kaiser and Andrew Warwick provide some general reflections on the usefulness of the works of Thomas Kuhn and Michel Foucault for a philosophy of scientific education (Kaiser and Warwick 2005). Kaiser and Warwick refer to Joseph Rouse, who incorporated insights from both philosophers in his philosophy of scientific practice. However, Kaiser and Warwick merely refer to Rouse as a reader and interpreter of Kuhn and Foucault. In this paper, I will argue that Rouse’s philosophy of scientific practice deserves to be studied in its own right and that his conceptualisation of scientific practices has important implications for the study of scientific education.

Throughout his work, Joseph Rouse has provided a sustained critique of a reified and representational account of knowledge. In *Engaging Science*, he has further developed his conception of scientific knowledge in terms of practices (Rouse 1996). In this work, Rouse refines his notion of practices, and uses it to present a dynamic view on (scientific) knowledge. Rather than being a thing possessed by knowers, scientific knowledge should rather be seen as a temporally extended process, only existing in and through its continuous repetition and reconfiguration.

I will argue that Rouse’s dynamic conception of scientific knowledge entails that education should occupy a central place in our analyses of scientific practices, as it is crucial in guaranteeing their temporal extension and sustenance. However, Rouse’s reconceptualization of scientific knowledge also has implications for our understanding of scientific education itself. I will work out these implications, focussing on Rouse’s non-subject-centered account of scientific practices. More generally, I show how Rouse’s philosophy of science entails that the study of scientific education should take the form of an integrated history and philosophy of scientific education.

**Intro: Scientific Education: A Neglected Topic**

Scientific education has recently started to attract the attention of historians and philosophers of science.[[1]](#footnote-1) This recent interest has however been preceded by a period of neglect. Part of this neglect can perhaps be explained by the influence of Kuhn’s criticism on “textbook science” with which he opened *The Structure of Scientific Revolutions* (Kuhn 1970 [1962], 1). In the aforementioned literature on scientific education, other possible explanations for this neglect have been brought forward, such as an obsession with novelty (Chemla 2014, 307-308) (Warwick 2003, 172).

In either case, the assumption is that educational practices are not the places to look if one is interested in “the real science”. This shows that assumptions about the nature of “real science” influence the way one perceives scientific education and its relation to scientific practice.[[2]](#footnote-2)

In this paper, I will provide a general reflection on Joseph Rouse’s philosophy of scientific practice in relation to the history and philosophy of scientific education. My general aims are the following. One the one hand, I show how Rouse’s philosophy of scientific practice conceives of these practices as activities which continuously remake the world and how education should be seen as one of the central processes involved. Second, I show how Rouse’s philosophy also has implications for our understanding of scientific education and how it should be studied.

**Local Knowledge**

In *Knowledge and Power* (1987), Rouse wants to develop an alternative to the representationalist, theory-centred accounts of scientific knowledge common in the philosophy of science. Instead, Rouse wants to look at science as a practical *activity*. The account of science presented in *Knowledge and Power* is described by Rouse as a “decentralized” account (Rouse 1987). In traditional philosophical views, scientific knowledge is often construed as propositional and universally valid knowledge of general laws. Technical and practical experimental abilities in this view derive from this knowledge (Rouse 1987, 21).

Rouse wants to put this image on its head. Rather than being derived from universal knowledge, the local grasp on a particular situation and the technical-experimental capabilities developed in this situation are the starting point of scientific practice. This leads Rouse to his localized account of scientific practice. In his own words:

“In scientific research, we obtain a practical mastery of locally situated phenomena. The problem is how to standardize and generalize that achievement so that is replicable in different social contexts. We must try to understand how scientists get from one local knowledge to another rather than from universal knowledge to its local instantiation” (Rouse 1987, 22).[[3]](#footnote-3)

A lot of effort in science is devoted to the creation of phenomena. For Rouse, this implies that in our analysis of science we should focus on the *labor*atory and the work that is being done there. Rouse refers to laboratories as ‘microworlds’ (Rouse 1987, 101-103) (Rouse 1996, 128-129). A ‘microworld’ is “a local reconstruction of the world” (Rouse 1996, 128) set-up with the aim of producing certain phenomena. To make this production possible, the ‘microworld’ is on the one hand isolated from the external world, to shield it from external causal influences. On the other hand, the ‘microworld’ contains a limited set of objects which are often purified and produced with the specific aim of being used in the ‘microworld’. Examples include substances used in chemistry, or special strains of bacteria and animals cultivated for use in laboratories (Rouse 1987, 23). By shielding the microworld from the external world, one has a better grasp on the effects of one’s manipulations of the microworld. By using prepared objects, one uses objects whose behaviour is stabilized and predictable. A ‘microworld’ is thus a reconfiguration of the world on which one has a practical and conceptual grasp (Rouse 1987, 100).[[4]](#footnote-4) Starting from this situation, one can then learn new things, either by introducing new objects in the ‘microworld’ or by manipulating the set-up of the ‘microworld’ itself (Rouse 1987, 102).

The production and manipulation of phenomena does not only depend on the use of prepared objects and the isolation of the microworld from external influences. Equally important are the skills of the experimenters. These skills are partly the result of the training received by the scientists, but also a result of the process of learning to work with the relevant objects and instruments used in the ‘microworld’ at hand (Rouse 1987, 38-39, 100).

**Transfer of local knowledge**

Although Rouse emphasises the local and situated character of scientific practices, this does not mean that the local knowledge produced in the laboratory cannot spread to other places. The question to be answered is thus “how scientists get from one local knowledge to another” or in other words: once a certain phenomenon is produced and stabilized in a certain ‘microworld’, how does it spread to other places?

Rouse identifies two processes through which this is done. The first process is one of “standardization” which involves the adaptation of the laboratory practices (or certain objects or instruments in them) to allow them to work beyond the highly controlled environment of the laboratory (Rouse 1987, 113) (Rouse 1996, 131).

A second process involves the adaptation of the outside world, or “the reconstruction of the surrounding world to resemble the laboratory in important respects” (Rouse 1996, 131). To put it in a slogan: “Science sometimes “work” only if we change the world to suit it” (Rouse 1987, 118). To illustrate this, Rouse refers to (among other things) the effort put in establishing and maintaining standards of measurement, and “the development of the chemical industry to manufacture the pure substances that chemical know-how presupposes” (Rouse 1987, 118-119).

The world we live in today is in a very large extent the result of these restructuring processes. Their success often conceals the effort that has been necessary to make certain things work and the maintenance that is needed to keep them working. The ubiquity of electricity can serve as a good example here.[[5]](#footnote-5)

Here we come to the centre of my first argument. The importance of reconstructing the world in the spread of results from the laboratory is what implies the importance of including educational practices in our historical and philosophical considerations of scientific practice and the spread of scientific knowledge. I already referred to the importance of skills in laboratory work. Several studies have pointed at the importance of these skills, and the necessity of other people acquiring them in order for certain phenomena to be reproduced.[[6]](#footnote-6) The reconstruction of the world to resemble the laboratory in important respects also involves remaking people in the world in order to make them resemble the people working in the laboratory, so to speak.[[7]](#footnote-7)

Let me now turn to some examples.

**The production and transfer of local knowledge: historical examples**

David Gooding’s analysis of Michael Faraday’s work leading to the electromagnetic motor serves as a good example of the importance of skill in the production of a phenomenon and as a clear example of standardization. Gooding shows how the series of experiments performed by Faraday can be seen as a learning process (Gooding 1990a). This learning process involved the acquisition of certain skills, the continuous design & redesign of the material set up, and a continuous reinterpretation of what was happening in the experiments. In the end, Faraday arrived at a somewhat stable configuration that allowed him to produce a phenomenon, namely “continuous motion of a current-carrying wire about a magnet” (Gooding 1990b, 160).

Gooding also discusses the specific way in which Faraday made it possible for this phenomenon to be reproduced in different contexts. To do this, he constructed a special device which he sent to a number of European scientists along with instructions for its use. The only thing the user had to do, was to fill it with a bit of mercury and connect the two ends with a battery. Once this was done, the device would display the phenomenon. The fact that the receiver did not have to do much was made possible by the design of the device, which, as Gooding puts it, “packaged the resources and skills [Faraday] had brought together” (Gooding 1990b, 155). Users did not have to go through the same process as Faraday in learning to work with and understand the behaviour of wires and electric needles. The device made by Faraday is thus a good example of what Rouse calls standardization, in that it allows for the phenomenon to be produced by less skilful people (Rouse 2006, 131).

Another example can be found in Andrew Warwick’s work on the history of the teaching of mathematical physics at Cambridge University. Warwick discusses the introduction of analytical mathematics from the Continent at Cambridge. The process as described by Warwick illustrates the two moves of standardization and reconstruction. On the one hand, the introduction of the new developments called for a reconstruction of the place where it was being imported. It necessitated people to learn new mathematical skills in order to be able to teach them themselves. Learning practices also changed with the examination process being adjusted and the importance of private tutors increasing even more (Warwick 2003, 77). On the other hand, it also involved processes of standardization, where French textbooks had to be reworked in order to be usable in the new context. This led to the production of textbooks specifically suited for use in the Cambridge educational system (Warwick 2003, 145).

Warwick also points at the spread of the teaching practices described in the book. The teaching practices common in Cambridge were at first a very idiosyncratic phenomenon, with some comparable methods being used in the early nineteenth century in the Ecole Polytechnique and Neumann’s physics seminar at Königsberg (Warwick 2003, 504). However, Warwick suggest that “from the early twentieth century virtually all major mathematical and theoretical physicists were trained by some form of the methods described” by him in the book (Warwick 2003, 504). To support this claim, Warwick refers to “a 1912 survey on the mathematical training offered to physicists in the major European countries and the United States”, conducted on behalf of the International Commission on the Teaching of Mathematics (Warwick 2003, 505). The results, Warwick says, show a remarkable homogeneity and also point towards the existence of “international concern for further standardizing and improving the physicist’s mathematical knowledge” (Warwick 2003, 505). Though further historical work needs to be done, this analysis suggest that the development and spread of teaching practices might also be analogous to the spread of laboratory practices as described by Rouse.

**Standardization & distribution of skill**

In our discussion of the device designed by Faraday, we have seen how it enabled users to produce the phenomenon without having to acquire the same skills as Faraday. Standardization thus allows skills to be “packaged” to use Gooding’s terms. Users only have to develop the skills necessary to *use* the instrument.

This use of standardized equipment and products is now very widespread in scientific practice. In our discussion of the notion of a ‘microworld’ we have seen how Rouse conceives of the laboratory as a local reconfiguration of the world in which specially prepared objects and instruments were used. Scientists typically no longer make these themselves, but rely on technicians or industrial processes to manufacture them. The objects and instruments used in everyday laboratory practices are bought by the scientists, rather than made.[[8]](#footnote-8)

Early modern experimentalists such as Robert Hooke and Petrus van Musschenbroek advised future experimenters that they should learn to design instruments themselves and have a good understanding of the instruments they are using.[[9]](#footnote-9) Nowadays, what a new scientist being initiated in the laboratory practice learns is to use and rely on a certain instrument (and by implication rely on the persons and processes in which the relevant skills are now embodied).[[10]](#footnote-10)

A good example of this is the use of statistical software. In an article on the impact of the SPSS or “Statistical Package for the Social Sciences” on research and teaching practices in sociology, Uprichard, Burrows and Byrne describe how the spread of the software not only impacted the skills that a practicing sociologists was expected to have, but also lead to a ‘black box’ approach to the software (Uprichard, Burrows and Byrne 2008, 612-613).[[11]](#footnote-11) The skill and knowledge related to the design and functioning of the software now resides with the mathematicians and computer scientists responsible for the software.

Some educational practices can also be seen as processes of standardization, providing standardized “objects” (or subjects) to other practices. Warwick refers to the fact that since the 1860s “the top universities have come to rely on secondary education to provide a steady supply of highly trained and motivated students” (Warwick 2003, 503). That is, in the same way as laboratory practices have come to depend on ready-made objects provided by other practices, educational processes at universities have come to rely on other educational processes providing them with “ready-made” students.

**Rouse on practices: implications for the history & philosophy of scientific education**

These examples already show how Rouse’s philosophy of science provides new perspectives on processes of scientific education. In what follows I will discuss some further implications of Rouse’s philosophy for the history and philosophy of scientific education. More specifically, I will focus on the implications of the views expressed in *Engaging Science* (1996). In the central chapter of the book, Rouse provides ten theses outlining his understanding of what “a practice” is. These could be summarized by the following terms (not Rouse’s):

* + 1. Temporal extension
	+ 2. Continuation
	+ 3. Normativity
	+ 4. Resistance and power
	+ 5. Reinterpretation and semantic drift
	+ **6. Stakes**
	+ **7. Non-subject/agent-Centered**
	+ **8. Material configurations**
	+ **9. Material-discursive**
	+ 10. Spatiotemporally open

In what follows, I will not go through all the theses, but will shortly focus on theses 6 to 9 and their implications for the history and philosophy of scientific practices.

**Stakes**

In his account of practices, Rouse argues that what the practice is about (what is at stake in the practice) is subject to continuous drift and contestation:

“(6) practices matter (there is always something at issue and at stake in practices and in the conflicts over their ongoing reproduction and interpretation)” (Rouse 1996, 135).

Taking part in the practice also means having a grasp of what the practice is about, why it matters. These stakes are not a-temporal entities, but are continually reproduced and/or contested during the temporal extension of the practice. This notion of the continuous reproduction and contestation of stakes is related to scientific education in two ways. On the one hand, views on what the practice is about influence what should be taught. On the other hand there are also discussions on what is at stake in the educational practices themselves: what should (scientific) education be about?

A good example can again be found in the work of Warwick, who points to different views on the nature and goal of university education and the role of mathematics therein. William Whewell for example saw mathematics more as part of a general liberal education for the intellectual elite. His opponent, William Hopkins on the other hand, adopted a “more utilitarian and technically meritocratic view of mathematical studies” (Warwick 2003, 107). This in turn led to different views on the way mathematics should be taught.

**Non-subject/agent-centred & historicity**

The next two theses relate to Rouse’s non-subject –or agent-centred view on practices, which is related to his view on activities as situated.[[12]](#footnote-12) For Rouse “practice” does not only refer to the activities of agents, but also to the configuration in which these actions take place. Actions within a practice are always meaningful actions. The meaningfulness of these activities in turn depends on “the relational complex within which [these activities] are intelligible” (Rouse 1996, 143). This complex is prior to the activities of the agents: “The agents who engage in practices thus belong to the practice, rather than the reverse” (Rouse 1996, 143).[[13]](#footnote-13) Practices thus provide the conditions of possibility for agency and subjecthood. Put differently, one can only have agency within a practice, but this performance of agency depends on other people, a structured environment, and specific tools used in the activities of the practice. On the basis of this, Rouse says that practices can more generally be characterised as “situated patterns of activity” (Rouse 1996, 150). The condition of possibility for agency is thus provided by the situation, specifically understood as “the relational complex of embodied agents in meaningfully configured settings for possible action” (Rouse 1996, 150).

This non-subject-centred view on practices and the emphasis on the situated nature of activity has implications for our understanding of education, and also for how we should pursue the analysis of educational practices. In Rouse’s view, one can only have agency and subjecthood by participating in a practice. These are not given, but attained. This not only emphasises the importance of incorporating education into our consideration of practices, but also forces us to reconceptualise what it is to be educated. Becoming educated in something goes beyond acquiring certain propositional knowledge, and even beyond acquiring the ability to perform certain activities, but involves what we could call a process of initiation or incorporation. As Rouse himself expresses it: “acquiring a physicist’s understanding of the world is not fully or readily separable from other aspects of one’s socialization as a physicist” (Rouse 1996, 132).

The prioritisation of the situation and the situated nature of learning also have implications for the way we should study scientific education. To begin with, it invites us to take this situation (in the sense outlined above) into account if we want to have a full understanding of how people are educated as scientists. Moreover, if scientific education is to be seen as an initiation or an incorporation into a certain practice, and if (as we have seen) the stakes of practices are continuously contested, the nature of scientific education can also be expected to vary historically. Analyses of scientific education should take this historicity into consideration. The only hope for a philosophy of scientific education thus lies in an integrated history and philosophy of scientific education.

**Conclusion**

To summarize, I hope to have shown two things. On the one hand, I have tried to show how Rouse’s philosophy of scientific practice implies that we should take scientific education seriously, it being one of the processes through which scientific practices change the world. On the other hand, I have also shown how Rouse’s philosophy of scientific practice has implications for the way scientific education should be understood and studied. One of these implications was that we should take into account the historicity of scientific education and that the only hope for a philosophy of scientific education lies in it being an integrated history and philosophy of scientific education.

This historicity does however not mean that the study of scientific education only has “historical” implications or relevance. I believe the history and philosophy of scientific education has the ability to function as a cultural study of science in the Rousean sense.[[14]](#footnote-14) However, this is a point that I cannot develop further here and which remains to be argued for another time.

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1. Several edited volumes on the topic have appeared (Bernard & Proust 2014) (Badino & Navarro, 2013) (Kaiser 2005). The presence of a chapter on scientific education in the *Handbook of Science and Technology Studies* shows that the topic is beginning to become established within the field (Mody & Kaiser 2008). And finally, Andrew Warwick’s history of the teaching of mathematical physics at the university of Cambridge has demonstrated the fruitfulness of a historical and philosophical study of science starting from educational practices (Warwick 2003). [↑](#footnote-ref-1)
2. Moreover, analyses of scientific education might also in turn lead us to rethink our views on scientific practice. This point has been made by Andrew Warwick and repeated by James Secord (Warwick 2003, 3) (Secord 2004, 665). Both state that the philosophical implications of taking scientific education seriously still need to be spelled out. [↑](#footnote-ref-2)
3. The notion of a “phenomenon” is taken over from Ian Hacking. Hacking comments on his own use of the term as being derived from the use of the term in physics and classical and pre-modern astronomy: “The Renaissance star-gazers meant both the regular observed motions of the spheres, and particular events, such as the occlusion of Mars, which they hoped would prove to be derived from some law-like structure of the heavens” (Hacking 1983, 222). Cf. Rouse: “By “phenomenon” Hacking means a manifest regularity in the natural world. It is not a private sensation but a public event that commands our attention. What distinguishes a phenomenon are its clarity and reliability. Phenomena are clearly discernible, and the *circumstances* of their occurrence (although not always their causes or their most adequate description) must be well understood” (Rouse 1987, 99). [↑](#footnote-ref-3)
4. Which is in turn situated in the broader practical grasp of one’s situation in the research context cf. Rouse 1987, 39. [↑](#footnote-ref-4)
5. For the work involved in the ‘electrification’ of Western societies, cf. Hughes 1983. [↑](#footnote-ref-5)
6. The *loci classici* on this are Fleck 2012 [1935] and Collins 1985. [↑](#footnote-ref-6)
7. Cf. Rouse: “The disciplines needed to establish and extend laboratory practices and achievements also include the habitual practices and skills through which people make themselves into competent, reliable participants in a more or less shared world. Who we are is in significant part whom we have made ourselves into through the cultivation of habits of mind and body. A familiar and pervasive example is literacy [...] Scientific practices include specific extensions of literacy, of course, but they also involve many other transformations of self” (Rouse 1996, 132). This passage also points to the role of learning processes in the extension of laboratory practices which we would not immediately label as “scientific education”, e.g. learning to use and rely on certain technologies in our daily lives, or learning to repair and maintain certain technological artefacts or systems. The idea of “learning to rely” on something will be discussed in the section on the distribution of skills. [↑](#footnote-ref-7)
8. See for example “The Controlled Environments Catalog” advertised by Fisher Scientific (<https://www.fishersci.com/us/en/scientific-products/forms/order-controlled-environments-catalog.html>). [↑](#footnote-ref-8)
9. See (Hooke 1705, 20) and (Van Musschenbroek 1731, XI-XII). It should be noted that both Hooke and van Musschenbroek also relied on instrument makers and other craftsmen (and their skill) for the construction of their instruments. Van Musschenbroek also acknowledges that “it is rare that those who philosophise are also so well versed in mechanics, that they understand the nature of machines, and are able to discover their defects” (1731, XII). [↑](#footnote-ref-9)
10. In general, we could thus speak of a distribution of skill and what I propose to call an ecology of knowledge. In the same was as in an ecological system organisms depend on products made by other organisms, in these examples practices rely on products made by other practices. [↑](#footnote-ref-10)
11. In his article on mathematics and social skills in the social sciences, Gibbs also refers to this “blacboxing” attitude: Gibbs, Graham R. 2010. ‘Mathemetics and Statistics Skills in the Social Sciences’. In *Responding to the Mathematics Problem: The Implementation of Institutional Support Mechanisms*, edited by C. M. Marr and M. J. Grove, 44–50. St. Andrews, Scotland: The Maths, Stats and OR Network., <http://www.mathstore.ac.uk/headocs/responding_to_the_maths_problem.pdf>. [↑](#footnote-ref-11)
12. And the related view on knowledge: “On my account, practices are not just agent’s activities but also the configuration of the world within which those activities are significant. Attributions of knowledge are thus more like a characterization of the situation knowers find themselves within rather than a description of something they acquire, possess, perform, or exchange” (Rouse 1996, 133). [↑](#footnote-ref-12)
13. In educational theory, the situated nature of learning has been emphasised and explored by Lave & Wenger 1991. [↑](#footnote-ref-13)
14. For Rouse’s notion of cultural studies of science, see the last chapter of Rouse 1996. [↑](#footnote-ref-14)