Science, Technology & Innovation Studies,
Special Issue 1, July 2006

ISSN: 1861-3675

STI Studies
www.sti-studies.de

The Topicality of the Difference Thesis

Revisiting Constructivism and the Laboratory

Martina Merz (Technology and Society Laboratory, EMPA St. Gallen and OSPS, University of Lausanne)

Abstract

Within science and technology studies, constructivism has never existed as a single variant but under alternative interpretations. In this article it is argued that the different variants have maintained their topicality in unequal measure. It focuses on two variants of constructivism: The first emphasizes the isomorphism of scientific and other practices and insists that there are no epistemic particularities in scientific knowledge production ("analogy approach"); the second accounts for the success of contemporary science by relating it to the specifics of scientific laboratories ("difference approach"). In this paper it is argued that the second variant can provide a set of challenging research problems that have not, to date, been sufficiently addressed in the literature. The problems center on the relation between laboratories and contexts of application, as well as on the concept of the laboratory and its possible extensions. In contrast, the issues associated with the analogy approach have been well explored in previous bodies of work. This article develops a research agenda for a constructivist account of knowledge production that may be employed within other discourses in the social sciences.

1 Introduction: Constructivism in Social Studies of Science

This article[1] addresses the claim that constructivism in science studies has lost its provocative gist and potential to surprise.[2] On the basis of the observation that, in the social studies of science, constructivism has never existed as a single variant but under alternative interpretations, the article proposes a rephrasing of this claim. What are these different variants and according to what criteria may they be distinguished? Surprisingly, only few attempts have been undertaken to sort through and systematically classify the different understandings of constructivism. One exception is an article by Sergio Sismondo (1993), who maintains that the construction metaphor has at least four different uses and interpretations. Sismondo's article received wide attention and was the subject of controversial discussion for two reasons: first, because of its attempt to bring some order into the muddle of constructivist interpretations; secondly, because of the way it evaluated the significance of these four interpretations for the practice of STS.

Sismondo differentiates constructivism with respect to the types of entities that have been constructed and identifies four types of entities: (a) *social objects* (e.g. knowledge, methodologies, habits) – the associated form of constructivism exhibiting affinity with "social constructivism" in the spirit of Berger and Luckmann (1966); (b) *conceptual entities* (e.g. theories, accounts, images) – the focus in this case being on how patterns or structures are generated from data and observations; (c) *artifacts* – herewith shifting interest to the level of material interventions in the laboratory; and (d) *objects of thought and representation*. The last variety, labeled also "idealist," "neo-Kantian" or "strong" constructivism, forms the most controversial interpretation as it asserts that material objects ("nature") are construed out of worldviews ("science"). Strong constructivism has been a matter of particular contention between philosophers of science and the more radical constructivists in the field of the sociology of scientific knowledge; the controversy then spreading to other audiences in the wake of what was to become known as the "science wars."

Sismondo's contribution to the debate on constructivism consists – which relates to the second issue above – in his ranking of the different constructivist interpretations by importance. In particular, he downplays "strong constructivism" by considering it to be the least important interpretation for actual work done in social studies of science. This has led Karin Knorr Cetina (1993) to counter with a "strong constructivist thesis," according to which "the world is slowly molded into shape in ever new ways through successive generations of (scientific) practice" (Knorr Cetina 1993: 560). Other respondents have contested Sismondo on different grounds. Peter Taylor (1995), for example, has criticized the specific attention accorded to the type of entities produced, suggesting instead that the focus of attention be the different processes of production. He also argues for a stronger emphasis on "the process of science in the making as a co-construction" involving a diversity of agents and components (Taylor 1995: 353; cf. also Sismondo 1995).

What we learn from Sismondo's text and the critical responses it has triggered is that constructivism in social

[1] I thank Richard Randell and two reviewers for their valuable comments on this article.

[2] See, for example, the call for papers of the 2004 Annual Meeting of the GWTF "Was kommt nach dem Konstruktivismus in der Wissenschafts- und Technikforschung" (Berlin, November 26-27, 2004).

studies of science is above all a multifaceted thing.[3] It comes in different interpretations, each of which may serve specific theoretical or practical purposes and be part of a dedicated research program. The debate also hints at the possibility that different variants of constructivism follow different trajectories. This idea will be further explored in the present text, albeit with a focus on a different scheme of constructivist interpretations. Two interpretations that follow from the science-as-practice approach in the social studies of science with its interest in the constructive elements of scientific production are juxtaposed. The first interpretation stresses the analogy of scientific practice and other forms of practice and asserts that there is no epistemic particularity in scientific production (analogy thesis); the second interpretation seeks to account for the remarkable success of contemporary science and hence inquires into the specifics of scientific production (difference thesis).

The proposed distinction, which to date has not been discussed systematically in the science studies literature, allows one to separate off one variant of constructivism which, I argue, opens up interesting perspectives for future research, from a second variant whose general mechanisms are today rather well understood. The present article thus addresses the topicality of the two approaches in a double sense: On the one hand, it investigates the potential of both approaches to raise interesting new questions and perspectives for future work. On the other hand, it explores the topicality of the two approaches in the sense of their "aboutness" (Reinhardt 1981)[4] through drawing out the topical fields to which they relate.

In section 2 the two constructivist approaches will first be situated in the science-as-practice approach and then introduced in more detail. The following sections address two issues which, it is proposed, should generate questions for further research: the header "transcending the laboratory" hints at the relation between laboratories and contexts of application, which is explored for each of the approaches (section 3); the concept of the laboratory and its possible extensions is discussed with particular reference to the "difference approach" (section 4).

2 Constructivism and Concepts of the Laboratory

An interest in the process of knowledge production emerged in the late 1970s, just a few years after the new sociology of scientific knowledge (SSK) had taken off. Both the constructivist approach and SSK are convinced that science is not to be investigated merely as a social institution (in the tradition of Merton) but that science's epistemic core is a matter of investigation in its own right. In respect to their perspectives on science's epistemic core, however, the two approaches are complementary. Whereas SSK focuses primarily on the social causes of the scientists' convictions and knowledge-beliefs – on science as knowledge – the constructivist approach turns its atten-

[3] This article will be concerned with constructivism in social studies of science only. It will not address other "Spielarten des Konstruktivismus," as Knorr Cetina (1989) denotes different varieties that range from "social constructivism" as mapped out by Berger and Luckmann (1966) to "radical constructivism" in sociology (for example, the work of Luhmann) and the empirical program of constructivism in the sociology of science. For a discussion of different interpretations of constructivism in the social sciences and humanities see Hacking (1999).

[4] A related notion of topicality is addressed in linguistics. Michael Lynch (1991) pursues a different notion of how knowledge production is "sited" by providing two examples of "topical contextures" that define spatial orders associated with complexes of equipment and practice.

tion to the constructive elements of scientific production – on science as practice. Interest in the process of knowledge production has led to a greater appreciation that science is a practical accomplishment. One of its most significant observations has been that scientific practice is firmly embedded in local environments and should, consequently, be investigated in situ, thus bringing the privileged sites of knowledge production into view – the scientific laboratories. The social analysts' interest in the laboratory and its goings-on has given rise to the "laboratory studies approach" – the exploration of the minutiae of everyday scientific practice through participant observation methods, combined with ethnomethodology and discourse analysis.[5]

The science-as-practice approach has led to constructivist interpretations that are intimately linked to conceptions of the scientific laboratory. I distinguish two complementary interpretations, both of which have been elaborated by the same set of authors and which represent different focal points and targets of argumentation. While the first contends that scientific practice does not substantially differ epistemically from other realms of social practice (2.1), the second explores the reasons for the success of science and, thus, zooms in on science's unique features (2.2).

2.1 Analogy Thesis

The first perspective views laboratory research as inextricably tied to the locales in which knowledge is produced (for an overview see e.g. Lynch 1997: chap. 3). The laboratory is seen as a repository of competences, practices, tools and resources that the scientists draw upon. Scientists exploit the contingencies of local contexts with respect to the equipment and research facilities at hand, the interactional circumstances, the conventions embodied in laboratories, the combined expertise gathered in a research team and the organizational setting in which it is embedded. Scientists draw on a whole repertoire of improvisations and tentative solutions, different forms of tinkering and embodied skills, as well as different techniques of persuasion and negotiation. The research problems, consequently, are locally constituted, as are the research objects, the tools, and the ways in which scientists handle and assemble all these elements. Out of this seemingly messy set of things and actions, scientists "produce order" (Latour/Woolgar 1979) as they conceal the messy traces of their work. This implies that science does not merely represent reality as it is "out there;" scientific work is constructive. What later appears as a natural phenomenon or as unproblematic data is the outcome of a complex production and selection process. Thus, scientific practice is also an interpretive, representational and literary activity. Data and other outcomes and products of scientific practice are rarely – some would say never – unambiguous, complete, definite and univocal. They retain a high degree of interpretative flexibility.

The observations of the locally situated nature of scientific work with its high degree of contingency as well as the negotiated character of all the steps that intervene in the process of fact construction have led laboratory analysts to the conclusion that "nothing epistemically special is happening" (Knorr Cetina 1995: 151) in scientific knowledge production.[6]

[5] The first laboratory studies were published in the 1980s, for an overview see Knorr Cetina (1995).

[6] For a detailed account of the local situatedness of research see Knorr Cetina (1984: chapter 2); for a specification of the concept "locally organized activities" see Lynch (1997: 125-133).

2.2 Difference Thesis

A second perspective identifies the laboratory as the paramount site of knowledge production in modern science. Although scientific knowledge is of course also produced at other sites, the laboratory has come to symbolize the power and success of science – a development that originated in the 19th century. Bruno Latour and Karin Knorr Cetina, among others, have convincingly maintained that this power relies on specific forms of object work that are performed in – and are constitutive of – the laboratory.

In his discussion piece "Give Me a Laboratory and I will Raise the World," Bruno Latour (1983)[7] argues that scientists gain strength in the laboratory by inverting the hierarchy of forces according to their research interests. They do this by reversing the scale of phenomena at will in the laboratory, making some objects bigger, others smaller. For example, organisms are isolated and cultivated in a suitable milieu, which allows them to grow exponentially and become visible to the scientist's eye. As a consequence, scientists are enabled to do things in the laboratory that are not feasible outside the laboratory, where the existing scales are unmanageable and cannot be negotiated. The variation of scales has another favorable effect: it enables scientists to multiply experiments at reduced cost, allowing for an increased number of trials and errors. As a consequence, the laboratory turns into a learning environment, "a technological device to gain strength by multiplying mistakes" (ibid.).[8]

Karin Knorr Cetina (1992) similarly argues that the laboratory is "an enhanced environment" (ibid. 116) and that this accounts for the success of science. The mechanism that brings this about is the reconfigurating of subject-object-relations to the scientists' advantage, which can be viewed as a generalized notion of Latour's scale reversal. In the laboratory the phenomena of investigation are removed from their natural context. Scientists reshape them in order to control their temporal and spatial accessibility and render them fit for experimentation.[9] Lab objects can be duplicated, standardized and made amenable to a full sequence of experiments (cf. Amann 1994). In addition, social relations are reconfigured – "upgraded" in Knorr Cetina's terms – and aligned with the specific requirements of the objects in the lab. For example, collaborations are forged to confront the object world optimally, with form and size of collaborations differing widely across fields. Another example is provided by scientists who assume the function of human measuring devices or who become important repositories of unconscious experience.

To summarize this perspective: Knowledge production is closely associated with a specific mode of relations between the scientists and their laboratory objects. The power of the laboratory stems from the reconfigurations that shift the balance of subject-object relations to the benefit of the scientists. This mechanism accounts for the

[7] For a thoughtful account that challenges Latour's claim that laboratories (in all cases) "raise the world" see Scott (1991).

[8] For the idea that the multiplication of errors allows for a reduction of uncertainty, see, in a different context, Donald MacKenzie's (2000) discussion of computer systems: "a computer system that errs frequently (and is therefore distrusted) is, under some circumstances, less dangerous than one that *almost* never errs" (ibid. 183).

[9] Objects are not only technically manufactured, they are also symbolically and politically construed (e.g. by way of literary techniques of persuasion) which resonates more closely with the characterization of laboratories according to the "analogy approach."

difference between the laboratory (and the subject-object-dynamics it defines) and other societal settings and turns it into an "enhanced environment."

Although they were developed by the same community of researchers the analogy approach and the difference approach have followed different trajectories and they have advanced at an uneven pace. The analogy approach has provoked a curious mix of praise, considerable attention and controversial reactions from colleagues, especially in its earlier years – and it was hotly debated once again by self-selected proponents of the sciences during what some have termed the "science wars" of the late 1990s. The difference approach, in contrast, has stayed largely out of the limelight.

The two variants have maintained their topicality in unequal measure also with respect to the associated research programs. The analogy approach has brought about a thorough understanding of the open, contingent and negotiated character of scientific work and of the processes and mechanisms it involves. Due to its earlier productivity and success one may hypothesize that the approach neither challenges nor surprises science studies scholars to the same extent any longer. By contrast the difference approach, which has never been as controversial and as publicized as its sibling, provides still today a challenging research agenda. To spell out what this challenge might look like, two sets of issues are discussed in the following two sections (3 and 4).

3 Transcending the Laboratory

Laboratory studies have convincingly demonstrated that knowledge production in the lab is a locally situated activity. This raises two important issues that concern the boundaries of the laboratory and which deserve further consideration. A first perspective on the relation of the laboratory and its boundaries focuses on how results that were locally produced in the lab can be successfully exported and transferred to other settings. What are the mechanisms through which scientific statements or facts transcend the laboratory and link up with very different problem contexts and societal settings? The two variants of constructivism provide different answers and raise further questions, which will be detailed in the next paragraphs. A second perspective focuses instead on the confines of the laboratory; that is, on the lab and its possible extensions. Such extensions, and their implications, are addressed through extending both the concept of the laboratory and the physical spaces available for empirical investigation (section 4). The two perspectives are separated here for analytical reasons, however, when addressed in the context of specific research problems in a dedicated project they will need to be considered jointly.

3.1 Analogy Approach

For the analogy approach, how statements or facts transcend the laboratory does not pose a specific challenge. If there are no epistemic differences between the practice of knowledge production in the laboratory and other kinds of (non-scientific) practice, as posited by this approach, then it should come as no surprise that the exporting of results beyond the boundaries of the laboratory should be, at least in principle, unproblematic. This still requires that the specific transfer mechanisms are spelt out in detail, which they have. The analogy approach argues for a continuity of practice. Through the identification of a variety of strategies that are employed by scientists, studies in this tradition have shown how local products are turned into universal scientific facts. One important strategy of scientists is to employ a full chain of representations, of which visualizations provide an interesting example. The visualizations with which scientists work do not simply portray nature; they are the result of a multilevel process of production, translation, and transformation. The intricate visualization and representation practices are conceived as a "transformation of rats and chemicals into paper" (Latour 1986) that not only fosters understanding of research problems and results but also assists scientists in communicating their results across local contexts and in convincing their colleagues of the work's importance and validity.

Another strategy involves decontextualization – the production of objectivity effects through a step-by-step removal of reference to local contingence: Scientists do not disclose the open, contingent, and negotiated character of practical work in their accounts but instead produce condensed and purified versions of what goes on in the laboratory. Objectivity effects derive from rhetorical procedures, through which statements are transformed into solidified facts. Scientists, consequently, seem to be simply "reporting natural facts;" the constructed nature of knowledge disappears from view.

The general mechanisms by which statements are turned into facts and then travel within scientific communities and cross the boundaries of science have been well documented in this approach; this does not seem to be the case for the second.

3.2 Difference Approach

From the perspective of the difference approach the answer is less obvious. How can one explain that what holds within the confined settings of a laboratory is also valid outside of it? One might rather hypothesize the contrary – that the reconfigurations performed in the laboratory transform the configured entities in such a way that the results obtained by manipulating them are not transferable to the "world" in an unproblematic manner. This hypothesis follows from the assumption of an asymmetry between the laboratory and the world that underlies the difference approach. The laboratory order appears as clearly distinct from the natural order, the laboratory being characterized by a "homing in" (Knorr Cetina) of natural processes. This observation thus calls for an explicit discussion of the transfer modes of laboratory outcomes and their respective validity. It may come as a surprise that the processes of what one may call "re-reconfiguration" – how laboratory outcomes are successfully embedded into socio-material contexts beyond the laboratory – has not received sufficient attention.[10] There are, however, several important exceptions.

In his study on Pasteur, Bruno Latour (1988) provides an original account of how what holds in the laboratory is rendered valid also for application in other settings. Latour explains Pasteur's success in the world outside the laboratory – measured, for example, by the effectiveness of the vaccine – by the fact that the external world had been made to comply with the laboratory conditions. The stables, for example, had to adopt strict hygiene conditions and the sheep were vaccinated. While Latour's argument is convincing for the case at hand, one wonders how instructive it is for other cases. Do fields beyond the laboratory imperatively need to be molded according to laboratory conditions for laboratory-produced knowledge to be successfully applied in practice?

A general framework for explaining the success of scientists is provided by Actor-Network-Theory (ANT), for which Pasteur and other studies are illustrative (e.g. Callon 1986; Latour 1988, 2005). According to ANT, success does not result from the truth of the results that are put into practice

[10] For a similar assessment, see Heintz (1993: 545-546, note 34).

but is a function of how the laboratory is positioned in society. Scientists must successfully manage a heterogeneous network of actants (human actors, natural objects, material entities, etc.), they must capture the interest of previously uninterested outsiders, enroll actants into the network as allies, and translate and stabilize the actants' interests. Translation – the re-interpretation or appropriation of others' interests into one's own – is the key strategy employed to mobilize broader support. The network needs to be stabilized for a scientific fact or result to assume significance outside its production context and be turned into a black box.

Actor-Network-Theory has been very influential due to its radical reformulation of nature-society relations and of the dynamics that unfold from unstable states of nature/society. In respect to the question under consideration here, it provides a general answer at a high level of abstraction. This leaves the door open to alternative interpretations, especially if one is interested in the minutiae of social-epistemic practice and the specific solutions that different problem areas and scientific fields elaborate to provide for and guarantee the transferability of laboratory results. If this is the focus, one will need to move beyond the (too) general frame of ANT. A few suggestions for relevant questions and instructive cases to be considered in more detail are sketched in the following.

3.3 The Game of Disembedding and Re-embedding

Knowledge about the transferability of scientific results to settings beyond the laboratory is distributed unequally throughout the scientific spectrum. Whereas scientific fields closer to application contexts need to handle the problem of transferability explicitly, other subject areas disengage from the issue to pursue a purely "internalist" research agenda. In so far as laboratory studies have focused on typical laboratory sciences, the question of the transferability of results has remained in the background, simply because it was of minor interest to the observed practitioners. This raises the question of which scientific areas might render an investigation of the game of "dis-embedding" and "re-embedding" practices particularly insightful and productive – the "game" denoting, on the one hand, the dynamic interrelation between the subject-object reconfigurations that account for the power of the laboratory and, on the other hand, the strategies that connect the ensuing outcomes with broader contexts. It should be noted, however, that what constitutes these "broader contexts" of interest has to be identified separately for each and every case. For example, the contexts may range from adjacent fields of research to other scientific areas or even to extra-scientific domains.

The first recommendation of this article is that the difference approach be brought to bear on studies of research areas that vary in the degree to which "strongly contextualized knowledge" (Nowotny et al. 2001) is produced. Environmental sciences, medical sciences and engineering sciences are instructive cases. To date very little is known about the dynamic relation between laboratory cultures and the strategies employed to ensure the practical validity of results, which raises the additional question of the origins of evaluative practices and standards in the sciences. For example, do contemporary societal preferences for knowledge that is certified according to scientific standards have an influence on the reconfiguration practices in scientific laboratories? A comparative perspective would provide interesting insights into both the field-specific practices and the more general mechanisms by which laboratory knowledge is exported.

The second recommendation is that science scholars explore more systematically the epistemic practices that account for the disembedding and the re-embedding of objects and results. In this context a focus on modeling practices is of considerable interest. Models of all sorts (physical models, prototypes, model systems, formal models, computer models, etc.) play an essential role in knowledge production in general, and in the reconfiguration of objects in particular. They have recently been taken up as prominent topics of investigation in science studies, albeit not sufficiently in respect to the perspective presented here (cf. Knuuttila et al., in press). In the following I will present one important example: computer simulation as an epistemic practice that navigates continuously between the requirements of object reconfiguration and outcome re-embedding, which has become a key epistemic strategy across a wide range of scientific fields (cf. for a recent overview Lenhard et al. 2006).

Phenomena are numerically configured to render them amenable to experimentation in simulation studies. In many cases, to construct the numerical models that underlie the simulation involves a complex chain of modeling steps and approximations (cf. Winsberg 1999). From this perspective the computer appears as a functional equivalent of the workbenches of a traditional laboratory science, and simulation studies are perceived as being performed in a digital laboratory. Simulation allows scientists to mimic, shape and experiment on natural, technical or formal processes and phenomena such as natural systems or research apparatuses. Scientists exploit these options for various purposes: they explore new spaces of action, probe the consequences of theoretical assumptions or investigate the dynamics of a natural system.

What is important in the context of the present discussion is that studies of simulation practices reveal the need to carefully consider the disembedding *as well as* the re-embedding dynamics of object work (cf. Merz 2006). This is due to the fact that a simulation study in many cases is not an end in itself: it is typically explicitly targeted to the solution of practical problems, as its application in the environmental sciences (e.g. climate research) testifies. In many cases, simulation studies simultaneously address a scientific problem and produce predictions of use to other (often non-expert) communities within or outside science. The scientists must actively negotiate the balance between the reconfiguration and the re-embedding requirements of the study: reconfiguration – the transformation of objects as they occur "in nature" into the objects worked on in laboratories – requires a form of disembedding. Reconfigured objects are easier to deal with and it is possible to extract results from them in ways that advantage the scientist precisely because they have been partly disembedded from their natural environments. The work of re-embedding is required to link up the outcomes of simulation studies with the practical problem that motivated the study at its onset. The mechanisms and strategies that are employed to ensure that the results can be successfully transferred to sites beyond the laboratory are context-dependent: they may vary with the considered scientific area, the concerned scientific problem or the public significance of the issue at hand. The practice of how to transcend the digital laboratory may also involve very different systems of reference. Simulation studies in fields like particle physics, for example, are disciplined by the parallel performance of "real" (in contrast to computer) experiments: simulation results need to prove themselves in comparison to "real data,"[11] which perhaps explains why the disembedding tendencies of simulation in particle physics tend to be controlled

[11] In this case the transfer needs to prove itself in yet another laboratory, which makes the digital lab a lab in (and a part of) another lab (cf. Knorr Cetina 1999).

and kept in closely observed bounds. Whether this is the case also in problem areas that are inaccessible by way of material experimentation is a matter for empirical investigation, as is the question of how the scientific validity of the results is assured in these cases.[12] A twist to these variations is cases where simulation itself becomes part of a strategy to ensure the transferability of experimental results to the context of application.

These observations illustrate that the scientific practice of modeling provides, first, an interesting field for investigating the transfer and transferability of scientific results beyond the narrow confines of its production context – the (digital) laboratory. Secondly, the study of modeling practice generates important questions regarding the power of laboratories, which can be asked of other laboratory practices for purposes of comparison. Thirdly, it allows us to review and refine the difference approach in constructivist science studies.

4 Extending the Laboratory

The difference approach raises a second set of questions, concerning possible extensions of the laboratory concept, the laboratory's variable and shifting position in the sciences, and the different laboratory forms that have developed in science and, potentially, in other societal realms.

The first question relates to the concept of the laboratory and the processes of object reconfiguration through which it is defined. As noted above, the notion of object reconfiguration can be productively extended to also include the alternate object worlds that are produced by computer simulation. Computer simulation allows for the constitution of digital laboratories in which the phenomena under investigation are amenable to extremely flexible reconfiguration and manipulation. In this case, scientists are required to negotiate the different ontological orders and epistemic features between the simulated and the material object worlds. In current scientific practice, digital laboratories assume different positions and functions in the knowledge production process. While simulation may serve in certain cases as a substitute for "wet lab" experimentation, it is exploited in juxtaposition to wet lab experimentation in many other cases. In particle physics, for example, simulation parallels, precedes, frames and complements other experiment-related activities, with each experimental phase drawing on simulation in specific ways (cf. Knorr Cetina 1999, Merz 2006). These observations hint at the possibility that different laboratory orders (digital lab, wet-lab, etc.) may become intertwined in the course of a scientific project.

A second issue concerns the relation between laboratory practice and other modes of knowledge production in science – and what implications this has for the laboratory concept and the constitution of its boundaries. In accord with the logic of the difference approach, the early laboratory studies singled out the knowledge-production mechanisms of typical laboratory sciences as their topic of investigation. This raises the question of whether other epistemic forms deserve more consideration than they previously have been accorded. For example, recent work in the sociology and history of science has devoted increasing attention to the field sciences and their knowledge production regimes (cf. e.g. Kuklick/Kohler 1996). Modern field sciences combine field measurements with laboratory work, while "labscapes" (Kohler 2002) either draw nature into the lab or bring the lab to the field. A traditional field science like astronomy can be conceived in its

[12] For the case of environmental sciences, see e.g. Oreskes (1998), Oreskes et al. (1994), Shackley/Wynne (1996), Wynne (1996).

present form as an image-producing laboratory science that transforms its phenomena in a computer-based laboratory and then processes them in the form of representations (cf. Knorr Cetina 1995). The clinical setting in modern biomedicine also constitutes a kind of field. An extended body of literature has begun to address the processes of mutual constitution between the laboratory and clinical practice (cf. Casper/Berg 1995). The lab-field border is managed and negotiated differently in different sciences. These observations suggest that a more systematic investigation of the laboratory's position and boundary practices in the context of other epistemic strategies and knowledge production regimes should be pursued. In line with the recent interest in the diversity of scientific cultures and the particulars of fact construction, a challenge for future investigations lies in the direct comparison of laboratory cultures (cf. Galison 1996).

A third complex of issues revolves around the question of whether laboratories exist outside the institutions of science and research, specifically, at the science-society boundary. Under the header "society as laboratory" Krohn and Weyer (1989) have brought to our attention new ways that science is included in society, defined as a coincidence of research and implementation. In this case, the implementation of knowledge is the condition under which knowledge becomes validated and through which new research questions are generated (in fields such as genetic manipulation and human experiments in space). This gives rise to a new experimental situation, characterized by the impossibility to set or influence its boundary conditions, and by the multiplicity of actors who perform according to different cognitive and evaluative categories. While the implied laboratory notion is distinct from the one underlying the difference approach, one wonders whether "real-world experiments" (Gross et al. 2003) in all instances are free of any form of subject-object reconfiguration that privileges the knowledge-seeking parties, be they scientists or others or both at the same time. This question is associated with both an empirical research program and a conceptual agenda. First, it is motivated by a desire to explore how the laboratory is an arrangement that, in its dynamic of subject-object reconfiguration, belongs specifically (and perhaps even exclusively) to the realm of science in the present time. Secondly, it is motivated by a desire to investigate whether the laboratory concept of the difference approach can be fruitfully applied to knowledge production regimes at other societal sites and, should this be the case, to explore what one might learn about such regimes. The research agenda that underlies the present text is thus not to be misunderstood as a reification of the difference approach: to assert that the difference approach still provides a challenging research agenda is not synonymous with accepting the claim that science is fundamentally different from other forms of societal practice.

5 Conclusions

The science-as-practice approach in the social studies of science has given rise to alternative interpretations of constructivism, two of which are revisited in this text. Both interpretations focus on the position of the laboratory in science. The first (the analogy approach) maintains that there are no epistemic particularities in scientific knowledge production, drawing on observations of the locally situated nature of scientific work. The second (the difference approach) accounts for the success of science by linking it to the specific reconfiguration processes that symbolize the scientific laboratory. This paper has argued for the continuing topicality of the difference approach and its capacity to generate challenging research questions. However, the fact that the difference approach is privileged in this text is not to be interpreted as an assertion of its superiority over the analogy approach, which has provided us with a rich and detailed account of the manufactured and negotiated character of fact making. The power and fruitfulness of the difference approach lies in its attention to the specific subject-object relations and the reconfiguration processes that make up the laboratory qua enhanced environment. Although this article has focused on the differences, the analogy approach and the difference approach represent two sides of one coin. They are complementary and not in contradiction and, due to their common roots, they share defining tenets (the situated nature of knowledge production, analyzing science as practice, etc.).

Earlier laboratory studies privileged the investigation of typical laboratory sciences in order to identify the mechanisms that would account for the success of science. A promising next phase of research, it has been argued in this text, would be to extend both the topics and the fields of investigation within the difference approach. The section entitled "Transcending the Laboratory" addressed the issue of how laboratory-produced knowledge can be exported successfully to application contexts beyond the narrow confines of the laboratory. This raises questions regarding the awareness of scientists of the limitations and uncertainties of laboratorization processes and regarding their strategies and priorities for pondering "doability" (Fujimura 1987) either in the laboratory or in practice – or their neglect to do so. It also raises questions regarding the boundaries of the laboratory and the division of labor spanning these boundaries, between those responsible for knowledge production in the lab and those responsible for managing the "export" of knowledge and its application. In addition, new modes of object configuration have been developed, such as computer simulation, that are of increasing importance and which define new types of laboratories that perform according to new rules. The section entitled "Extending the Laboratory" addressed related questions by inquiring into the hybrid forms of knowledge production, in which one or different laboratory regimes complement, interfere with, or parallel other knowledge production regimes, both within science and across the institutional borders of science and research. The assumption of considerable variability in configuration forms, accompanying social forms, institutional arrangements, temporal structures, spatial organizations, and so forth calls for an empirical program from a comparative perspective.

Can laboratory-like features of knowledge production be identified at the boundary of science and other societal realms, or even in areas of society altogether removed from science? A constructivist perspective informed by the difference approach has the potential to further our understanding of the so-called "knowledge society." From a constructivist perspective, knowledge is not a mere resource; rather, the focus of interest is epistemic strategies of knowledge production and validation. With an eye to furthering our understanding of the knowledge society it is recommended that those epistemic forms and social arrangements that transcend the scientific laboratory be investigated more thoroughly than they have been to date, which would allow us to conceptualize the knowledge society as heterogeneously situated epistemic practices. A debate between constructivist science studies scholars and proponents of the knowledge society model has not (yet) taken place. This article is an attempt to identify issues and concepts that may serve as a point of intersection and contact between the two fields.

6 References

Amann, Klaus, 1994: Menschen, Mäuse, Fliegen. Eine wissensoziologische Analyse der Transformation von Organismen in epistemische Objekte. In: *Zeitschrift für Soziologie* 23, 22-40.

Berger, Peter L./Thomas Luckmann, 1966: *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*. New York: Doubleday.

Callon, Michel, 1986: Some Elements of a Sociology of Translation. In: John Law (ed.), *Power, Action, and Belief: A New Sociology of Knowledge?* London: Routledge and Kegan Paul, 196-233.

Casper, Monica J./Marc Berg (eds.), 1995: *Constructivist Perspectives on Medical Work: Medical Practices and Science and Technology Studies* (special issue), *Science, Technology, & Human Values* 20 (4).

Fujimura, Joan H., 1987: Constructing 'Do-Able' Problems in Cancer Research: Articulating Alignment. In: *Social Studies of Science* 17, 257-293.

Galison, Peter L. (ed.), 1996: *The Disunity of Science*. Stanford, CA: Stanford University Press.

Gross, Matthias/Holger Hoffmann-Riem/Wolfgang Krohn, 2003: Realexperimente: Robustheit und Dynamik ökologischer Gestaltungen in der Wissensgesellschaft. In: *Soziale Welt* 54 (3), 241-258.

Hacking, Ian, 1999: *The Social Construction of What?* Cambridge MA: Harvard University Press.

Heintz, Bettina, 1993: Wissenschaft im Kontext: Neuere Entwicklungstendenzen der Wissenschaftssoziologie. In: *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 45 (3), 528-552.

Knorr Cetina, Karin, 1984: *Die Fabrikation von Erkenntnis: Zur Anthropologie der Wissenschaft*. Frankfurt a.M.: Suhrkamp.

Knorr Cetina, Karin, 1989: Spielarten des Konstruktivismus. Einige Notizen und Anmerkungen. In: *Soziale Welt* 40 (1/2), 86-96

Knorr Cetina, Karin, 1992: The Couch, the Cathedral, and the Laboratory: On the Relationship between Experiment and Laboratory in Science. In: Andrew Pickering (ed.), *Science as Practice and Culture*. Chicago: University of Chicago Press, 113-137.

Knorr Cetina, Karin, 1993: Strong Constructivism – from a Sociologist's Point of View: A Personal Addendum to Sismondo's Paper. In: *Social Studies of Science* 23, 555-563.

Knorr Cetina, Karin, 1995: Laboratory Studies: The Cultural Approach to the Study of Science. In: Sheila Jasanoff et al. (eds.), *Handbook of Science and Technology Studies*. Thousand Oaks: Sage, 140-166.

Knorr Cetina, Karin, 1999: *Epistemic Cultures. How the Sciences Make Knowledge*. Cambridge MA: Harvard University Press.

Knuuttila, Tarja/Martina Merz/Erika Mattila, in press: Computer Models and Simulations in Scientific Practice. In: *Science Studies: An Interdisciplinary Journal for Science and Technology Studies* 19 (1), forthcoming.

Kohler, Robert E., 2002: *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology*. Chicago: University of Chicago Press.

Krohn, Wolfgang/Johannes Weyer, 1989: Gesellschaft als Labor: Die Erzeugung sozialer Risiken durch experimentelle Forschung. In: *Soziale Welt* 40 (3), 349-373.

Kuklick, Henrika/Robert E. Kohler (eds.), 1996: *Science in the Field* (special issue), *Osiris* 11.

Latour, Bruno, 1983: Give Me a Laboratory and I will Raise the World. In: Karin Knorr Cetina/Michael Mulkay (eds.), *Science Observed: Perspectives on the Social Study of Science*. London: Sage, 141-170.

Latour, Bruno, 1986: Visualization and Cognition: Thinking with Eyes and Hands. In: *Knowledge and Society: Studies in the Sociology of Culture Past and Present* 6, 1-40.

Latour, Bruno, 1988: *The Pasteurization of France*. Cambridge: Harvard University Press.

Latour, Bruno, 2005: *Reassembling the Social: An Introduction to Actor-*

Network-Theory. Oxford: Oxford University Press.

Latour, Bruno/Steve Woolgar, 1979 (2nd ed. 1986): *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills CA: Sage.

Lenhard, Johannes/Günter Küppers/Terry Shinn (eds.), 2006: *Simulation. Pragmatic Constructions of Reality - Sociology of the Sciences, vol. 25*. Dordrecht: Springer, in press.

Lynch, Michael 1991: Laboratory Space and the Technological Complex: An Investigation of Topical Contextures. In: *Science in Context* 4 (1), 51-78.

Lynch, Michael, 1997: *Scientific Practice and Ordinary Action: Ethnomethodology and Social Studies of Science*. Cambridge: Cambridge University Press.

MacKenzie, Donald, 2000: A Worm in the Bud? Computers, Systems, and the Safety-Case Problem. In: Agatha C. Hughes/Thomas P. Hughes (eds.), *Systems, Experts, and Computers. The Systems Approach in Management and Engineering, World War II and After*. Cambridge MA: MIT Press, 161-190.

Merz, Martina, 2006: Locating the Dry Lab on the Lab Map. In: Johannes Lenhard/Günter Küppers/Terry Shinn (eds.), *Simulation: Pragmatic Constructions of Reality – Sociology of the Sciences, vol. 25*. Dordrecht: Springer, 155-172, in press.

Nowotny, Helga et al., 2001: *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. London: Polity Press with Blackwell Publishers.

Oreskes, Naomi, 1998: Evaluation (Not Validation) of Quantitative Models. In: *Environmental Health Perspectives Supplements* 106 (S6). Retrieved March 17, 2004, from http://ehp.niehs.nih.gov/members/1998/Suppl-6/1453-1460oreskes/oreskes-full.html

Oreskes, Naomi/Kristin Shrader-Frechette/Kenneth Belitz, 1994: Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences. In: *Science* 263, 641-646.

Reinhart, Tanya, 1981: Pragmatics and Linguistics: An Analysis of Sentence Topics. In: *Philosophica* 27, 53-94.

Scott, Pam, 1991: Levers and Counterweights: A Laboratory that Failed to Raise the World. In: *Social Studies of Science* 21 (1), 7-35.

Shackley, Simon/Brian Wynne, 1996: Representing Uncertainty on Global Climate Change and Policy: Boundary-Ordering Devices and Authority. In: *Science, Technology, & Human Values* 21(3), 275-301.

Sismondo, Sergio, 1993: Some Social Constructions. In: *Social Studies of Science* 23, 515-553.

Sismondo, Sergio, 1995: Reply to Taylor. In: *Social Studies of Science* 25, 359-362.

Taylor, Peter, 1995: Co-Construction and Process: A Response to Sismondo's Classification of Constructivisms. In: *Social Studies of Science* 25, 348-359.

Winsberg, Eric, 1999: Sanctioning Models: The Epistemology of Simulation. In: *Science in Context* 12 (2), 275-292.

Wynne, Brian, 1996: SSK's Identity Parade: Signing-Up, Off-an-On. In: *Social Studies of Science* 26 (2), 357-391.