Science in Context **26**(2), 203–213 (2013). Copyright © Cambridge University Press
doi:10.1017/S0269889713000033

Introduction: Knowledge in the Making: Drawing and Writing as Research Techniques

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Argument

Drawing and writing number among the most widespread scientific practices of representation. Neither photography, graphic recording apparatuses, typewriters, nor digital word- and image-processing ever completely replaced drawing and writing by hand. The interaction of hand, paper, and pen indeed involves much more than simply recording or visualizing what was previously thought, observed, or imagined. Both writing and drawing have the power to translate concepts and observations into two-dimensional, manageable, reproducible objects. They help to develop research questions and they open up an interaction between the gathering of phenomena and the formation of theses. Related to the manifold studies of representational activities in the sciences and the humanities, this topical issue tries to refine our understanding of the capacities of drawing and writing as research techniques; i.e. as productive epistemic practices. In particular the contributions address three aspects: the material conditions and configurations of the "scene of drawing and writing," the involved procedures of production, and the languages of inscription.

I. The Setting

Even in today's high-tech environments, drawing and writing are still among the most widespread scientific practices of representation. Neither photography, graphic recording apparatuses, typewriters, nor digital word- and image-processing ever completely replaced drawing and writing by hand. The interaction of hand, paper, and pen or pencil indeed involves much more than simply recording or visualizing what was previously thought, observed, or imagined. Both writing and drawing have the power to translate concepts and observations into two-dimensional, manageable, reproducible objects. That is, they help to shape and develop research questions and in this way open up an interaction between the gathering of phenomena and the formation of theses. In fact, the activities of writing and drawing constitute one of the most critical steps in epistemic processes: the step from (potentially) ambiguous data to stable facts, and from provisional ideas to guiding concepts. They "circumscribe a space, and at the same time are inscribed into a space that lies between the materialities of the experimental systems and the spirituality of the final written communications

that are eventually, at a later date, released to the scientific community" (Rheinberger 2003, 624).

In recent decades, an interdisciplinary field of inquiry has emerged from discussions about representation in the sciences. However diverse the subjects of those studies have been, in principle they have shared one premise in common; representation is conceived as an active intervention that partly limits and enriches what is represented, and partly enables entirely new experiences. In the history of science, the discussion was originally dominated by research fields like particle physics (Galison 1997) or molecular biology (Rheinberger 1997) with their sophisticated tools and apparatuses for making visible rather fragile, transient, and imperceptible research objects. Here, and in the multitude of studies in scientific photography, film, and recent computer-based imaging and 3D-modeling technologies as well, the contribution of these devices to the evolution and definition of research objects has grown easier to recognize. In most cases, entire phenomena, or at least decisive aspects of them, could not be investigated without the intervention of representational techniques, which lend them their characteristic shape and properties. In this respect, drawing and writing appear as comparatively simple practices. In modern societies, moreover, they are deeply embedded in everyday life and usually act as handy tools that warrant no further attention as techniques with specific capacities. Nevertheless, drawing and writing also add to these epistemic spaces in between primary research operations and published accounts.

The substantial role of writing and related inscription practices in research is not at all new. Laboratory journals, research notebooks and academic correspondence have been used by historians of science as sources for reconstructing case studies and exploratory pathways for a long time (e.g. Holmes 1974, 1985, and 1991–93; Buchwald 1994; Todes 2002; Holmes, Renn, Rheinberger 2003; Steinle 2005). In this approach, scientific inscriptions were rarely studied for their own sake; what was primarily at stake were the research questions and findings documented in the records. Credit is due to scholars from science studies, such as Karin Knorr Cetina, John Law, or Steve Woolgar and Bruno Latour with their seminal study *Laboratory Life*, for their focus on "paperwork" as an activity in its own right (Latour and Woolgar 1979; Knorr-Cetina 1981, chaps. 5 and 6; Law 1986). Latour in particular makes us aware that both in laboratory and field research, this kind of work should not be undervalued as a bureaucratic pursuit. His inquiries into the scientific life of biochemists, soil experts, and botanists revealed how inscriptions of the most diverse kinds enabled scientists to handle, systematize, condense, circulate, mobilize and negotiate their objects (Latour 1990 and 1999, chap. 2). One effective mode of paperwork in this respect is the use of index cards and similar compilation systems (e.g., on Linnaeus' system of information management, see Müller-Wille and Charmantier 2012).

A different approach has been taken by scholars who focused on the symbolic operations connected to writing and notational systems (cf. Klein 2001; Barberousse 2003; Bogen and Thürlemann 2003; Krämer 2003; Warwick 2003, chap. 3; Kaiser 2005; Meyer-Krahmer 2012). From their analysis of the symbolic and diagrammatic

languages of mathematicians, chemists, physicists, and philosophers, it became quite clear that the impact of those languages resided in the potential for manipulating signs like phenomena. While Latour's notion of "paperwork" described inscriptions solely as the infrastructure of knowledge transmission, the second approach, which can be related to Ursula Klein's notion of "paper tools," delved into the particular role of formal inscriptions in the formation and exploration of research objects. Similar functions can be attributed to more ordinary uses of writing, such as in notebooks, lab journals, and field notes (see, for example, Welfelé 1998–99; Hoffmann 2003; Rheinberger 2003; Daston 2004; te Heesen 2005; Gunn 2009; Bourguet 2010; Wickman 2010). In the context of medicine, a number of studies has shown how closely the organization of work and the production of knowledge are related to writing reports, filling out forms, and collecting and reworking files (cf. Mcintyre 1978; Craig 1991; Berg 1996; Berg, and Bowker 1997; Engstrom 2003; Sammet 2007; Hoffmann 2008; Bernet 2009; Hess and Mendelsohn 2010; Mendelsohn 2011; Ledebur 2011). Likewise, scholars have evaluated the basic techniques in the humanities, such as note-taking and excerpting (cf. Becker and Clark 2001; Décultot 2003; Trüper 2007 and 2011; Rößler 2008; Blair 2010; Ortlieb 2010, chaps. 5 and 7; Hensel 2011).

In the last two decades, a third perspective on scientific inscriptions has gained a certain prominence, namely, the interest in drawings and note-taking practices as means of observation. Especially in (historical) case studies on astronomy and microscopy, the production of records and sketches has been described in terms of a modeling, stylization, or professionalization of perception (Dennis 1989; Bredekamp 2000 and 2009; Schickore 2002; Schulze 2002 and 2005; De Rijcke 2008; McIver Lopes 2009; Daston and Lunbeck 2011; Anderson and Dietrich 2012). Drawing and writing in these cases assume the role of instruments that guide attention and control sight. According to a distinction introduced by the French philosopher Gilbert Simondon, tools are used to manipulate the world, whereas instruments are characterized by a feedback structure, because they are able to inform the user's senses (Simondon 1989). The differentiation could easily be applied to our field of study. In the case of Klein's "paper tools," inscriptions are used to experiment symbolically on certain phenomena, while the power of paper instruments resides primarily in their capacity to convey or strengthen perceptual information. Nevertheless, the distinction is only of a certain heuristic value because Simondon himself emphasized that in practice both functions were more or less inextricable from each other. Even very simple objects like a hammer can be described as a tool as well as an instrument, depending on the operation exerted. You can use a hammer to drive a nail into a certain surface, but you can also utilize it in order to learn more about the properties of a certain material, e.g. if it is solid or hollow. Because of this constant intermingling of both functions, we did not systematically differentiate between "tools" and "instruments," but use the terms more or less as equivalents.

The discussion about "paperwork" has a counterpart in literary studies and art history. Since the 1980s, the French school of *critique génétique* has been analyzing literary

manuscripts as documents of writing processes. Although mainly interested in the gradual emergence of the "final text," scholars developed here a subtle understanding of the inner dynamic of drafting, writing, and reworking (cf. Hay 1989; Gréssilon 1994). Ideas about the operational aspect of writing, originally developed in the discussion of the oral/literacy divide in cultural anthropology in the 1960s, were renewed with a view toward formal sign systems and iconic aspects of writing (Krämer 2003; Grube, Kogge, and Krämer 2005). The material dimension of literary writing garnered attention in studies on the interaction between writing processes and different writing tools like the pen or typewriter (Stingelin 2004). The recent suggestion of a genuine "aesthetics of the tool" goes a step further, exploring literary texts and artworks both as tools and as dependent on their tools of production (Holland and Strätling 2010). Likewise, art historians have shifted their attention from pure connoisseurship and from the functional analysis of drawings as preliminary studies for more eminent paintings, sculptures or buildings, to the appraisal of the draftsmen's own logic of composing, expressing, and reflecting (e.g. Rosand 2002; Bryson 2003; Evans 2000; Busch, Jehle, and Meister 2007; Bach and Pichler 2009).

Following these lines of inquiry, this issue of *Science in Context* focuses on drawing and writing in the context of knowledge production over the last two hundred years. Our central concern is to develop and evaluate a conceptual framework for refining our understanding of the capacities of drawing and writing as tools of research. More specifically, the essays in this volume aim at finding a descriptive language for three aspects of paperwork.

First, writing and drawing may be framed as a configuration of instruments, materials, sign systems, the writer's or the draftsman's body, *and* the research object, with its respective time-specific circumstances. Analysis, therefore, focuses on the setting in which writing and drawing take place. In such settings, every element is dependent on the other, and all act as specific constraints on the processes of drawing and writing. Some of these configurations, like the use of the *camera lucida* in microscopic drawing (Fiorentini 2006 and 2008; De Rijcke 2008; Wittmann 2013), proved to be quite stable for the last two hundred years, while others were more open to the individual manipulations and strategies of the particular actors involved. Even if one deals with the sometimes highly idiosyncratic writing, note-taking, or drawing techniques of individual scholars, one can discern specific regularities. In this respect, literary studies have established the term "writing scene," which may be conceived as an "unstable ensemble of language, instrumentality, and gesture" (Campe 1991, 760). Similarly, in art history, drawing has been analyzed as an act that depends greatly on historically specific constellations of hands, drawing materials, and other technical infrastructure (Meister 2007; Pichler and Ubl 2007; Gründler, Hildebrandt, Nasim, and Pichler 2012).

Second, attention will be paid to the specific temporal and spatial organization of the different acts of drawing and writing – that is, to the procedures, as we would like to call this internal formation. Usually, drawing and writing practices implement procedures, i.e. an order of steps that translates into a characteristic spatial arrangement

of traces in temporal sequence. The specific procedures may vary in their degree of complexity. They may be highly personal, as in the marginalia of a manuscript or printed book, or entirely standardized, as in the drawing of a closed-circuit diagram. They may follow widely shared traditions, as in the case of the production of a list, or they may become the subject of explicit exercise, as in acquiring the skills associated with shading techniques. In any case, procedures are dependent on the context. Records in the lab differ as much from observational reports in the field as sketching astronomic phenomena in an observatory differs from studying a nude in the artist's studio. Furthermore, procedures are flexible in their use. For example, a list can be an aid to memory, and may also be an explorative instrument. In general, attention given to the procedures may help identify ways in which drawing and writing processes deploy instrumentality, comparable to the functions and effects of apparatuses and tools.

Finally, in addition to the configuration and procedure, the languages of inscription in their plurality are of eminent importance for the analysis of writing and drawing. Depending on the respective functions of recording, processing, and constructing, a variety of modes of graphic representation may be discerned. These notational or sign systems might be highly conventional or exceedingly individual and provisional. Arguing against Nelson Goodman's theoretical distinction between pictorial representations and notational systems (Goodman 1976), we will emphasize the permanent intermingling of both domains in practice. Sometimes exploratory processes engender syntactic junctions between written and pictorial notes, thereby creating rebus-like recording techniques. The contributions will also emphasize that the generative and epistemic effects of writing and drawing frequently reside in the parallel use of and systematic interplay between the two techniques, and sometimes even in the methodological subversion of their difference.

II. The Papers

Today, drawing and writing belong to a common set of cultural techniques. Once skills have been adopted during childhood, they become routinized. One can even assume that for an adult person of average education, writing and basic drawing skills (for example, the ability to visualize spatial relations on a site map) fall into the category of tacit knowing. Matthew Eddy's paper "The Shape of Knowledge" can be read both as a reminder and as an excavation of the hidden, imperceptible traditions of Western graphical culture. His study of late eighteenth-century Scottish educational texts is informed by the idea that the material form of presentation, i.e. the layout of a book and its elements, must themselves be considered as instructions. Aspect and content here go hand in hand when graphic patterns of the book, like columns or paragraphs, simultaneously train and stabilize the spatial orientation of young readers. Notwithstanding the particular context, it is obvious that many of Eddy's observations

on the loop between teaching materials and teaching aims can be transferred to other, more recent educational settings. His paper gives us a clear idea that concealed beneath explicit sign systems and languages of visualization, basic schemes of graphical order and visual orientation are at work that shape drawing and writing acts fundamentally. Spontaneity and creativity, which are very often related to scientific drawing and writing scenes, here appear bounded to an antecedent set of figures and operations.

Whereas Eddy's paper draws attention to the mechanisms through which basic and almost inconspicuous scholarly techniques were transmitted, Omar Nasim investigates the development of ever more complex observational routines in nineteenth-century astronomy and the crucial role that drawing played in this context. Nasim's study is devoted to once highly disputed celestial phenomena known as nebulae, objects that because of their very shapelessness and ambiguity seemed to evade scientific description and classification. Drawing proved to be a crucial technique in mastering this difficult problem. Nasim presents a comparative analysis of three research programs centered around the question of nebulae: those of John Herschel, Lord Rosse, and William Lassell. In all three cases, an array of drawing techniques was used, ranging from the simplest forms of sketching to elaborate oil paintings, and in all cases, the recording process was not limited by the use of one of those techniques; on the contrary, the astronomers and their teams developed complex and laborious procedures supporting celestial observation. Nasim interprets the development of these refined procedures as a reaction to the technical constraints of astronomical observation. Herschel and Lord Rosse realized that the restricted time of observation might be extended or slowed down by applying a multi-step procedure of graphical recording.

In contrast to drawing, where the operational aspect seems ever present, the creative function of writing is far more difficult to demarcate. One widely accepted view is that writing can stimulate the rise of new ideas; doodling, for example, is very often considered in this sense. A second, quite popular concept focuses on writing as a kind of catalytic process. Here, in the course of writing, and induced by the challenge "to write," hitherto scattered fragments of insights and thoughts coalesce into a coherent argument, almost to the surprise of the writer. In both cases, writing seems to be more a medium with all its magical connotations than a genuine instrument. The main argument of Christoph Hoffmann's contribution is that the instrumental quality of writing must be related to the procedures implemented by the writing gesture. As in Nasim's study of nebula drawings, temporality plays a decisive role here. Discussing two examples from the notebooks of the Austrian physicist and philosopher of science Ernst Mach, Hoffmann shows how open questions become more concrete either by listing and marking items, as in his first example, or by iterating them, as in his second example, i.e. slightly differentiating an initial note from various subsequent notes. The sequence of steps does not lead to a conclusive answer to the initial problem, but rather produces a more finely grained idea of what is at issue in the respective contexts. Writing procedures are thus defined as a set of rules that may be culturally pertinent, like the list, or else shaped by highly personal preferences, like Mach's iterative procedure in

the second example. The critical point, however, is that from this point of view, writing in scholarly contexts must be acknowledged as a combination of material actions and non-material rules or algorithms about "how to proceed."

In the most trivial sense, writing is very often equated with writing down. The primary characteristic of writing would thus seem reduced to the function of preserving or retaining something. This might be the reason that very often only the mnemonic merits of writing are recognized, whereas organizational and explorative possibilities escape attention. In her study of the early *Cahiers* of French writer and essayist Paul Valéry, Karin Krauthausen takes the opposite position. Instead of solely reading the notes, i.e. instead of comprehending and discussing what has been noted down, she focuses on the gradual emergence of Valéry's *Cahiers* as working tools. Starting with the material configuration of the writing scene, Krauthausen examines how a repertoire of procedures gradually takes shape in the process of note-taking. The right format of the notebook and a regular time for note-taking are just as much part of this as the testing and refining of a certain number of writing procedures. The common feature of these procedures is their aim not for closure, but for a permanent breaking-off and beginning-anew of the writing process. Valéry's practice of noting is of course very much shaped by the notion that his *Cahiers* form a work of their own. Nevertheless, Krauthausen's analysis offers a number of suggestions for inspecting scholarly notes. In particular, we may learn to study the paperwork of the sciences and the humanities with an eye toward the inventive play (and the many ideas which never make it into final drafts). In this regard, note-taking amounts, foremost, to a tool for transcending what one already knows.

This capacity of notes for resolving unproductive situations in research processes seems to be closely related to a certain semantic mobility of inscriptions; scientists can switch easily between writing, sketching, and scribbling – and in this sidestepping exists the possibility for finding new relations between as yet unrelated elements. Another privileged genre for productive escapes are diagrams, which have recently been characterized as a third tool for knowledge production between writing and drawing (Bogen and Thürlemann 2003; Krämer 2009). Anouk Barberousse draws attention to this space in between the realms of text and image. She discusses the role of diagrams in theoretical physics and hints at the great affinity between graphical diagrams and models in general. Taking a theoretical model of polymer absorption and two types of grafted surfaces as her example, Barberousse shows how physicists construct diagrams to create new models and to gain a deeper understanding of them. Against the widespread view that diagrams are merely cognitive aids or imprecise placeholders for more precise concepts, she acknowledges the fictional value of diagrams in physics. Following her argument, diagrams provoke an imaginative game that allows physicists to defy concepts, leading to contradictions between models and commonly accepted theories. Borrowing a term developed by the philosopher Kendall Walton, Barberousse conceives diagrams as "props" and "generators of fictional truth," i.e. as objects that enhance the scientist's ability to imagine the phenomenon represented by the model.

Whereas the former contribution is dedicated to figures that support theoretical development, the last text in the volume by Barbara Wittmann deals with drawing – in close relation to Omar Nasim's article – as a technique of morphological description. Wittmann's case study addresses the practice of drawing in contemporary biological taxonomy, especially with the so-called type drawings, i.e. the graphic illustrations created when a species is first described or when its definition is revised. Such drawings are expected to represent the type specimen with the greatest possible accuracy because in taxonomic practice the illustration functions as a mobile representative of the relatively immobile specimen. Nevertheless, the function of type drawings is not restricted to its use value as "immutable mobiles." They not only visualize and record important traits of a species, but also redirect the scientist's observations and are therefore deeply involved in helping scientists detect these traits. Despite the historical distance between the studies of Nasim and Wittmann, both authors characterize the process of recording visual phenomena as a complex procedure that involves not only one drawing technique, but a wide range of graphical modes that allow for the differential exploration of observed phenomena as well; and in both cases, the ongoing translation of celestial objects and specimens into newer and newer drawings supports and enables the very constitution of the research object.

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