Written Communication
27(3) 259–292

Reprints and permission: http://www.sagepub.com/journalsPermissions.nav
DOI: 10.1177/0741088310371777
http://wc.sagepub.com

Writing Material in Chemical Physics Research: The Laboratory Notebook as Locus of Technical and Textual Integration

Chad Wickman[1]

Abstract

This article, drawing on ethnographic study in a chemical physics research facility, explores how notebooks are used and produced in the conduct of laboratory science. Data include written field notes of laboratory activity; visual documentation of *in situ* writing processes; analysis of inscriptions, texts, and material artifacts produced in the laboratory and assembled in notebooks; and an in-depth interview with an expert chemist whose research and writing formed the basis of this investigation. Findings from this study suggest that the notebook occupies a negotiated space between the scientist's contingent response to exigency in the laboratory and the genre-specific strategies that he or she deploys to communicate his or her work outside the laboratory. This text, the author argues, might therefore be understood as a *locus* in the sense that it facilitates a reflexive process whereby inscriptions are used both to interpret a-perceptual chemical phenomena in time, and, through their inclusion and integration in the notebook, to discipline that interpretation

[1]Auburn University

Corresponding Author:
Chad Wickman, Department of English, Auburn University, 9030 Haley Center, Auburn, AL 36849
E-mail: cwickman@auburn.edu

over time. Tracing the way inscriptions move between material synthesis, on the one hand, and text production, on the other, this article ultimately offers a methodical approach for investigating how the material, technical, and symbolic dimensions of writing and text converge in a modern scientific workplace.

Keywords

scientific writing, laboratory notebook, multimodal text production, visual inscription practices, writing and materiality, materials science, constructivist semiotic

Laboratory notebooks have often provided scholars with novel insights into the relationship between everyday writing activity and the material, technical, and symbolic dimensions of scientific knowledge production. Diverse in scope, this body of scholarship has examined notebooks from a number of disciplinary perspectives. Bazerman (1988), for instance, investigates the distributed writing processes through which Arthur Holly Compton drafted, revised, and published findings related to quantum theory; notebooks specifically enable him to explore the material and social constraints that scientists must grapple with in the conduct and communication of their empirical inquiry. Bazerman (1999) has also examined the collaborative nature of notebook production and how this genre of scientific writing helped Thomas Edison and his colleagues coordinate their expertise in the invention and development of electric light. As he suggests, the laboratory is a "locus of communication" (p. 75), and notebooks are essential to the ways in which communication itself gets organized, distributed, and documented through various representational forms.

Campbell's (1990) study of evolutionary theory provides further insight into the relationship between note making and processes of scientific discovery. He argues, specifically, that Charles Darwin's notebooks reveal an "unbroken dialectical continuity" (p. 86) between his early theorizing of natural selection—bound up, Campbell suggests, in the practice of rhetorical invention—and later arguments presented in *Origin of species*. Notebooks in this way help to merge contexts of discovery and justification in the sense that they provide a record of scientific theory as it undergoes revision over time, space, and audience presentation. In a similar spirit, Gross (2006) investigates Darwin's acts of self-persuasion in the *Red notebook* and how these arguments were later developed for the broader readership of *Origin of Species*. Notebooks, he claims, provide a means for examining how evolutionary theory itself evolved from a primarily mental debate between Darwin and himself to a more public transaction that adopts and enacts different rhetorical strategies (see Crick, 2005; Gruber, 1974).

Scholarship outside the field of writing and rhetoric studies has also contributed important insights into notebooks as genre of scientific writing. Gooding (1989, 1990a, 1990b; see Tweney, 1991; Tweney & Gooding, 1991), for example, has traced the ways in which nonverbal (tacit, personal) knowledge informed Michael Faraday's study of electromagnetism and his discovery of the electromagnetic motor. Mapping the material and conceptual dimensions of "discovery paths" in Faraday's notebooks, he suggests, reveals the ways in which thought, action, and human agency converge in the construction of experimental knowledge (Gooding, 1990a, pp. 176-177). Similarly, Holmes explores the "investigative pathways" of scientists like Antoine Lavoisier and Hans Krebs (Holmes, 1984; see also Holmes, 1985, 2004). Notebooks, for him, are useful resources for the study of science because they help to illustrate how inquiry at the local level gets transformed into new theories and monumental discoveries that potentially shape the very structures within which that science is practiced (Holmes, 1987, p. 234; see also Holmes, 1990).

The diversity of research involving scientific notebooks speaks to their richness as an object of investigation (see Holmes, Renn, & Rheinberger, 2003). Indeed, as the above studies demonstrate, notebooks provide a constructive lens through which to examine invention and discovery in the history of science—and how, specifically, scientists have historically relied on these texts as a means to negotiate both the materiality of experimental practice and the broader sociocultural milieus within which their research is situated. What I would like to consider here, however, as a way to complement existing studies, is how this genre of scientific writing shapes meaning making and communication in a modern scientific workplace. Notebooks offer an apt object of study in this regard: not only are these texts typically assembled in the context of dynamic scientific activity; they also tend to include a variety of symbolic resources—linguistic, visual, mathematical, three-dimensional—that scientists deploy, sometimes spontaneously, to document, warrant, and circulate the outcomes of their research.[1]

Writing, Notebooks, and the Textual Construction of Material Reality

Situating notebooks in the context of laboratory science offers the type of grounded investigation that has animated much writing scholarship over the past two decades. Indeed, studies have often looked to “minor” texts (Witte, 1992, p. 249; see also Medway, 1996; Winsor, 1994), like notebooks, as a way to theorize the material and semiotic dimensions of disciplinary and workplace writing activity (see Ackerman & Oates, 1996; Dias, Freedman, Medway, & Paré, 1999; Haas & Witte, 2001; Hull & Nelson, 2005; Prior, 1998; Smagorinsky, Zoss, & Reed, 2006). This scholarship has shown, among other things, that the concept of *writing* itself is as diverse as the settings within which it is enacted as a literacy practice: whether in everyday contexts, academic disciplines, or professional workplaces. The study of writing, Witte suggests, should accordingly reflect that diversity and not, therefore, focus exclusively on “linguistic systems of meaning-making” (p. 240). Provocative then, this suggestion is all the more relevant today as digital technologies continue to transform the semiotic landscape, and, thus, the ways in which writers make and communicate meaning textually (see Bezemer & Kress, 2008; Kress, 2003; Kress & van Leeuwen, 1996, 2001).

Witte’s (1992) “constructivist semiotic” specifically offers a generative theoretical basis for examining how texts construct meaning for writers and their audiences. Within this framework, c*ontext* refers to the sites, and the situations, within which texts are produced and interpreted (see Chin, 1994); *text* refers to the objects of production and interpretation,[2] and *intertext* refers, broadly, to the means by which individuals come to understand texts in relation to other texts and utterances (see Bakhtin, 1935/1981; Kristeva, 1986). This triad, Witte suggests, moves beyond a Saussurean theory of signs where meaning is realized through difference within a closed system and adopts, instead, a Peircian view where meaning derives from the writer or reader’s ability to integrate context and text with his or her existing knowledge (intertextual connections, interpretants). Making this move is important for elaborating a culturally viable theory of writing, for once a triadic model of signs and sign making is introduced, meaning can be understood as a *product of* rather than a *prerequisite to* communication—which means, in turn, that writing can be understood as a process of meaning construction rather than meaning transmission. Applied to the study of scientific notebooks, this theoretical framework opens up a space for exploring the relationship between scientists, the semiotic resources they bring to bear in their research and communication, and the extent to which writing, broadly understood, is a situated, meaning-constructive activity.

Witte’s constructivist approach has often been brought to bear on studies that examine the nonlinguistic components of meaning making and textual communication. Medway (1996), for instance, presents a study of architects who utilize multiple forms of representation in their design work (see Ackerman & Oates, 1996; Dias et al., 1999; Medway, 2002). He specifically examines the ways in which architects, drawing on a range of semiotic modes, bring new conceptual realities into existence prior to, and apart from, any physical structure that may result from such conceptualization. This, for him, is one way to differentiate between writing as technical and writing as epistemic; that is, architectural writing/design does not simply facilitate the production of buildings but actually brings new knowledge into the world—or, at least, into the architects' minds—prior to any attempt at technical construction. Medway's work in this way speaks to the power of writing as a "semiotic process" (p. 479) that describes material reality just as it shapes the very processes through which that reality is envisioned, designed, and constructed in the world.

Haas and Witte (2001), in a study that investigates the production of an engineering standards document, also illustrate the relationship between texts and the material realities they purport to represent. Yet in contrast to Medway's architectural designs, the standards document must be produced with an extant context in mind—involving a channel easement and a stream bank—and must, therefore, deal with an obdurate reality that, while represented in the text, exists apart from that text in a very real sense. The engineers must, then, through their writing, negotiate the relationship between the proposed easement and the existing, and always shifting, embankment; they do this using a combination of verbal language, visual representation, and embodied gesture. Haas and Witte's study confirms that text production involves much more than a linear process of inscribing linguistic marks in graphic space. Indeed, these authors demonstrate that writing, broadly understood, is a complex, multimodal activity through which writers engage not only with the material conditions of text production but also with the material contexts to which texts respond (see Hull & Nelson, 2005).

Situated studies of writing in general have helped to theorize the materiality of text production and the ways in which writers construct and communicate meaning related to the physical world. Few studies to date, however, have examined the function and production of texts in settings, like scientific laboratories, where the very nature of reality is an object of investigation. Medway's study of architects does examine the relationship between conceptual designs and anticipated physical structures; Haas and Witte likewise provide insights into the relationship between embodied representation, texts, and an always-changing material landscape. With scientific research, however, physical reality is a question that must be answered. It *is* the focus of investigation. The study of scientific notebooks, then, though it can draw upon existing writing research, must grapple with a different set of epistemological questions related to the construction not only of documents or structures but also of entities whose existence is often open to speculation. Thus, in this project, I sought to address the following research questions:

Research Question 1: How do notebooks function in the context of day-to-day scientific work?
Research Question 2: What types of writing and inscriptional practices inform notebook production?
Research Question 3: How do scientists use notebooks to transform the material and technical dimensions of laboratory work into durable communal knowledge?

This article explores these questions through a case study involving one chemist, Dave, the tasks he performs to synthesize materials used in physics experimentation, and the notebook he assembles as a means to record and communicate his research.[3] I warrant this focus on two grounds. First, the notebook helps to illustrate the range of *inscriptions* (see Latour, 1987, 1988) and semiotic modes that chemists deploy in their technical work and textual documentation: from linguistic script to chemical structures to three-dimensional chromatography plates.[4] Accounting for these semiotic resources reveals how this text, in tandem with the technical work Dave performs, facilitates the production of new "metamaterials"—not found in nature—while conferring epistemic status on those materials through a multimodal rendering of chemicals, procedures, and outcomes.[5] Tracing the way inscriptions move between the tasks involved in material synthesis, on the one hand, and the tasks involved in text production, on the other, this study shows how a-perceptual chemical processes are made textual and how laboratory notebooks in turn shape the way scientists rhetorically warrant and communicate the outcomes of their research.

Findings from this study suggest that the laboratory notebook is a constructive resource through which scientists transform the materiality of laboratory practice into semistabilized disciplinary knowledge. For Dave in particular, this text is constructive in at least three ways: (1) physically, as in the inscriptions and semiotic modes it draws together in the same graphic space; (2) conceptually, as in the way those inscriptions and modes enable him to visualize chemical processes that he cannot perceive directly in the laboratory; and (3) rhetorically, as in the way the notebook justifies his findings for an anticipated future audience—whether himself at a later time or members of the scientific community with whom he might share his work. The notebook, I will show, thus occupies a negotiated space between the scientist's contingent response to exigency in the laboratory and the genre-specific strategies that he deploys to communicate his work outside the laboratory. This text might therefore be understood as a *locus* in the sense that it facilitates a reflexive process whereby inscriptions are used both to interpret a-perceptual chemical phenomena in time, and, through their inclusion and integration in the notebook, to "discipline" that interpretation over time.

Background for the Study

The setting for my research, a liquid-crystal physics and materials sciences institute (hereafter institute), proved ideal for investigating questions related to scientific notebooks and to scientific writing more broadly. The institute is home to an interdisciplinary doctoral program in chemical physics, and the faculty, a mix of professors trained in physics and chemistry, teach as well as manage their own research groups. I spent a considerable amount of time interacting with various members of the institute; the design for this study, however, was specifically oriented toward a group headed by Dr. Maxwell, a senior physicist and one of the institute's associate directors. Group research varies but is primarily structured around two interrelated activities. First, members produce materials that either have a liquid crystal phase or that might be combined with other materials in the design and development of new technologies, from liquid crystal displays to flat lenses (see Collings, 2002; Palffy-Muhoray, 2007). Second, they study and characterize the non-linear optical properties of the materials they produce. Participants ranged from full professor to visiting professor to postdoctoral fellow to advanced graduate student to first-year graduate student to undergraduate intern.

For approximately 1 year, I was part of the group's day-to-day activities. To name a few, I attended daily morning meetings where the group gathered to drink coffee and discuss the nuts and bolts of lab activity and individual research projects; I observed activity that crossed between the two main laboratory spaces (chemical and laser labs); I observed office activity, including data analysis and work with computer simulations; I attended weekly group meetings where lab members shared their work and discussed their progress; I attended "brainstorming sessions" where different lab members worked together to solve a common problems; I attended impromptu meetings where lab members presented and revised their work prior to giving posters or Power Point presentations at local and national conferences; I attended weekly seminars from visiting scientists; and, basically, I was involved as an observer in any number of everyday activities: from producing materials to constructing equipment to conducting experiments to preparing and running simulations.

Through my research, which takes the form of observational field notes, interview transcripts, and visual and textual artifacts, I identified three practices within the group that contribute to its overall research output: materials production, physics experimentation, and theoretical physics modeling and simulation. This article focuses on material production, however, because it best exemplifies the material, technical, and symbolic functioning of notebooks in the context of laboratory work. Physicists in the group often create materials for their own experiments, but I focus here on Dave, a postdoctoral fellow with a PhD in chemistry and the only certified chemist in Dr. Maxwell's employ. The bulk of Dave's work consists of producing material samples for the group, for collaborators in the Institute, and for collaborators in other laboratories. Production of samples in this case is not just a material means to an experimental end; it is also an indispensible way to maintain professional relationships and contribute to a body of disciplinary knowledge within the liquid-crystal-physics community. Yet this can happen only if a minimum of two criteria is met. First, the end result of material production must be a "good" sample, one that is usable, testable, replicable, and, essentially, knowable; second, and following from the first, the production process must be documented textually to confirm whether or not samples are indeed "good." My research has examined the ways in which notebooks contribute to this process.

Method

Investigating notebooks *in situ* presented two main challenges in this study. First, I needed to identify and describe how Dave's notebook functioned in day-to-day laboratory work; in doing so, I had to contend with a dense network of inscriptions and texts involved in that work. Second, I needed to analyze and explain the ways in which the notebook contributed to the technical production and textual verification of material samples as epistemic objects (see Rheinberger, 1997).[6] I met these challenges, in part, by adopting a grounded-theory approach to data analysis (Glaser & Strauss, 1967; Strauss, 1987). Briefly, this approach is designed to build theory—in my case, a substantive theory of notebook production and use in a laboratory setting—which can be traced to specific data points and analytical procedures. The process of building theory involves working closely with data, engaging in open, axial, and selective coding, developing core categories for analysis, and generating hypotheses that can be examined and refined through ongoing theoretical sampling and comparative analysis. Three methods formed the basis of my data collection procedures: observation, inscription collection and visual documentation, and in-depth interview (see Table 1).

Table 1. Methods, Aims, Output, Analysis

Method	Aims	Output
Observations	Observe Dave at work, document his practice, gain insight into how the notebook functions as part of day-to-day inquiry, and examine the relationship between notebook and inscriptions produced in the lab.	Field Notes. Approximately 100 pages across 3 phases of inquiry: 6, 4, and 2 months.
Visual documentation and inscription collection	Visually document and collect texts and inscriptions that Dave uses and produces in the laboratory, and examine the relationship between notebook and inscriptions produced in the lab.	Dozens of my own photographs; graphic renderings of Dave's work; dozens of Dave's photographs and renderings of his work.
Interview	Collect language Dave uses to discuss notebook and inscriptions, check my own analysis and hypotheses about the relationship between notebook and inscriptions produced in the lab.	1 interview with Dave for a total of approximately 45 minutes of talk; 18 single-spaced pages of transcribed text.

Observations

Throughout the first phase of my inquiry, which lasted approximately 4 months, I spent an average of 10 to 12 hours per week making observations in the laboratory space where Dave conducts the bulk of his research. My strategy for making field notes was to construct an inventory of observable texts, inscriptions, objects, actions, and writing practices. These observations, discussed in greater detail in what follows, led me to focus on the ways in which the notebook was embedded in specific laboratory tasks (see Bracewell & Witte, 2003). Through this focus, I was eventually able to tease out relationships between inscriptions, the notebook, and the ways in which Dave uses both to interpret and communicate the material-cum-epistemic outcomes of his technical work in the laboratory.

Visual Documentation and Inscription Collection

In addition to field notes, I also generated a visual record of laboratory activity. This method enabled me to document and analyze, for example, through digital photographs, the ephemeral markings recorded on writing surfaces and the technical processes that are enacted in the flow of day-to-day research. In addition to my own visual documentation, however, I also collected inscriptions, texts, and material artifacts that Dave offered to me (as copies) or that I photographed on my own. These included graphic displays, pages from notebooks, images of equipment, photographs of material samples, and so on. Essentially, the production and collection of visual inscriptions offered a useful means to analyze (1) what inscriptions look like, the forms they take, and the media through which they are realized; (2) how texts are composed, through inscriptions, over time/space; and (3) how the notebook, as a genre of scientific writing, shapes the practice of material production.

Interview

The interview reported in this study served two distinct but interrelated purposes. First, it enabled me to supplement my analysis through recorded talk with the scientist himself. Having a record of Dave's own language proved essential for investigating the ways in which he perceives his work and writing as part of that work.[7] Second, the interview enabled me to learn about scientific concepts. Similar to visual inscriptions, I could take the interview home, transcribe it, and study the basics of the scientific inquiry that constituted the focus of my research. Generally, because this interview was more open-ended than formal, I was able to collect discourse about a variety of subjects that, while directed by my questions, gave way to Dave reflecting and commenting on his research, writing, and use of texts in the laboratory. This was a helpful tactic, given my aim in conducting the interview itself; that is, because I used it to supplement my analysis, I was able to learn about different aspects of scientific work that I may not have thought to inquire into on my own.

Analysis and Results

This section describes and analyzes the relationship between Dave's notebook and the technical work he performs as a chemist. I begin by discussing how I came to focus on the notebook in light of the constellation of other texts used and produced in the laboratory; I follow by examining how inscriptions produced in the laboratory get integrated into the notebook; and I conclude by showing how, through this integration, the notebook helps to legitimize material samples as epistemic objects. I make this final move, specifically, by examining the technique of thin-layer chromatography (TLC)

Table 2. Texts, Production and Use, Relation to Material Output

Text	Production and use	Relation to material output
Lab notebook	Used and produced in the lab.	Primary source of documentation that serves as a durable record of laboratory work.
Recipe book	Used in the lab.	Provides procedural knowledge for synthesizing materials and producing samples.
Journal articles	Used in the lab.	Reference for envisioning, checking, and supplementing work on materials.
Manuals	Used in the lab.	Resource for constructing equipment and instruments.
Catalogs	Used in the lab.	Resource for ordering raw chemicals and for ordering instruments and equipment that facilitate synthesis.
Group website	Produced in office, on the basis of notebook entries.	Resource for communicating information related to material samples. Provides a direct link between laboratory and broader scientific community.

and how the result of this technique, a TLC plate, connects the notebook to other tasks involved in material production. More precisely, the plate is both a material result of chemical processes that Dave enacts in the laboratory and an inscription that does textual work in communicating that process. Tracing this relationship enables me to articulate how material becomes textual and how Dave uses his notebook to respond not only to local exigence—for example, evaluative work in the laboratory—but also the broader communicative needs of his group, the Institute, and other members of the scientific community who may be interested in his research.

Dave utilizes a range of texts to complete the steps involved in generating material samples (Table 2). The notebook, however, among all the texts I observed being used in the laboratory, is the only one that is actually assembled in tandem with specific laboratory tasks. This is an important categorical distinction in the sense that it links Dave's *in situ* research activity—the procedures involved in material synthesis—with the semiotic resources he deploys—inscriptions, modes—to record his work and thereby transform it into durable and replicable textual knowledge. The notebook in this way is a key site for examining the relationship between the technical and textual, and, thus, for understanding how Dave negotiates the material and a-perceptual dimensions of his laboratory work.

Just weeks into my study, I observed that Dave's notebook played a regular part in his research and day-to-day writing activity. The initial observations I made of him using and composing his notebook, however, did not strike me as unusual or, to some extent, especially relevant. Indeed, they seemed to be more or less a mundane part of laboratory life for this working chemist. Consider the following field note excerpt taken from the first week of my observations:

- Dave uses sticker to label—date and contents;
- Replica then goes in lab book—after going on product;
- Actually writes out long hand in his book;
- Dating new chemicals that arrived (writing as mnemonic, durable);
- Writes in his notebook as he completes activities (weighing, mixing, etc.);
- Weighing white powder on scale—notebook laid out next to him;
- Concocts/creates materials for experiments;
- Writes as he goes: linguistic text, equations, numbers/amounts, basically a record of his activity;
- Mixes with liquid and then photographs (using digital camera);
- Pictures offer affordance of examining visual appearance.

This excerpt speaks to Dave's more or less routine work in the laboratory. His routine would often involve obtaining a "recipe" for completing a material synthesis, one that came from his notebook, a so-called recipe book, a journal article, or some combination of texts; he would weigh out individual substances on a digital scale; he would combine the substances in a vial or some other receptacle; he would synthesize them; and he would, finally, attempt to characterize the outcome of that synthesis using a technique such as TLC. While completing these tasks, Dave would typically record his steps in his notebook: whether by hand with a pen, by taping in printouts from word processing or other scientific software programs, or by taping in inscriptions that resulted directly from techniques he performed in the laboratory (see Figures 1A & 1B). One aim of notebook production, in this case, is to record processes and procedures so that the output of Dave's work—a material sample—can be checked against the textual record he has constructed.

Field notes involving the notebook remained at a more or less descriptive level throughout the duration of my research. Yet the more time I spent observing Dave in the laboratory, the better I became at identifying and, to some extent, understanding the terms and concepts that informed his research and writing practices. Coming to grips with this work was not a completely analytical process. Indeed, my ability to comprehend laboratory

(A)

(B)

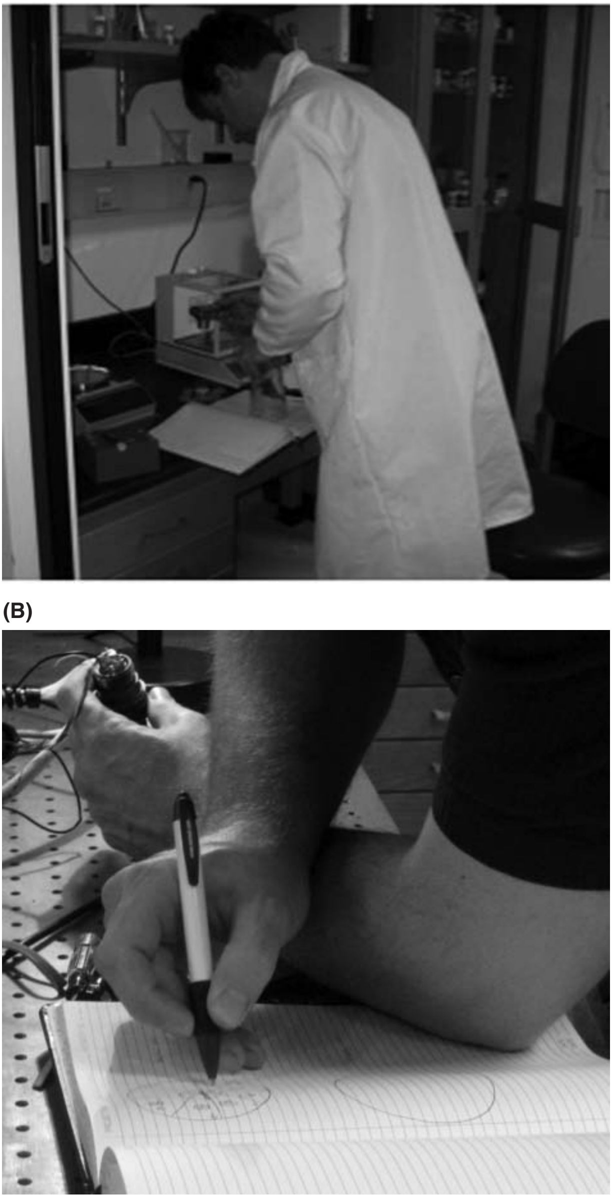

Figure 1. Dave documenting procedures in notebook (A) and (B)

activity, and thus the role of Dave's notebook in that activity, also came from immersion in the site, for example, in the laboratory, in group meetings, in seminars, and, importantly, from conversations—some recorded, many in passing—which I had with scientists about their work. At times, even, Dave invited me to ask him questions as he completed procedures in the laboratory. Consider the following field-note excerpt from the approximately the fifth month of my study:

- *In chemical laboratory*
- *Dave reading his notebook*
- *Starts writing in it*
- *Picks it up and goes over to the scale*
- *I ask him what he's working on*
  - *Making elastomers*
  - *Purifying chemicals*
- *Reading from his notebook as he measures out substance and weighs it–literally pauses with bottle and scoop in hand to check notebook*
  - *Notebook as meditational means*
  - *Modalities present as meditational means*
- *Photo-crosslinking elastomers with UV light*
- *Dave explains it to me a bit (cross-linking)*
- *Picks up and looks at it (sample) in light*
- *Dave: "Too bad it's not as pretty" as one made before (cool blue color)*
- *Two tasks going at once (or stages in process):*
  - *Mixing materials (chemical compounds) for elastomer samples*
  - *Photo-crosslinking elastomers*
- *Notebook is a key element in these processes.*

At least two general activities stand out in the above excerpts. On the one hand, Dave's notebook provides a textual reference that he can consult as he completes specific tasks. It is similar, in this way, to other texts found in the laboratory. On the other hand, however, the notebook is a living document that is constantly being produced, and, thus, is constantly undergoing revision over time. Furthermore, as an object of production, the notebook serves its own dual purpose. Specifically, Dave uses it to document routine procedures (e.g., labeling chemicals, weighing substances, synthesizing materials), and he uses it to document the material results of those procedures (e.g., an ostensible sample that may eventually be used in physics experiments). The first consists of more or less straightforward recording of methodical steps; the second consists of an interpretation—something of a reflective or evaluative moment—where he examines his results on the basis not only of

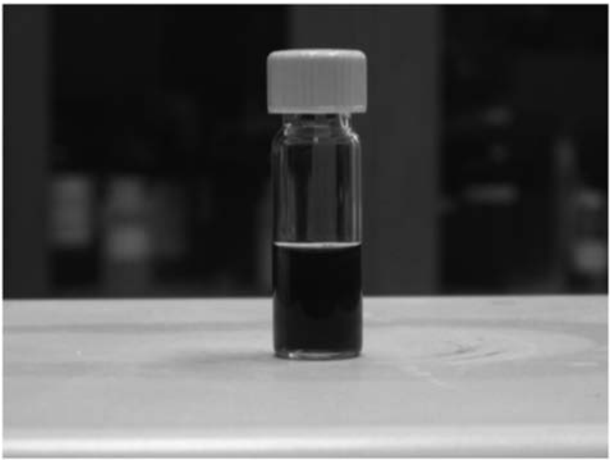

Figure 2. Photograph of material sample

recorded procedures but also the techniques he uses to confirm the material in question as a verifiable sample (see Figure 2).

As a functional text, the notebook does an undetermined amount of work in the laboratory. By this I mean, simply, that my study could not possibly account for the range of uses to which the notebook was deployed as a resource for Dave's meaning making or communication. Yet some uses are more apparent than others. Notebooks, for instance, help to distill dynamic scientific activity—for example, working with materials and instruments—into a series of discrete procedures so that the resulting text, while stylistically related to the person who composed it, actually emphasizes objects and procedures rather than the individual scientist who produced or completed them. This, I would argue, constitutes a move to objectify material processes and highlights the "known," that is, that which is documentable and replicable. As Dave mentioned to me in an interview, "The main purpose of a lab notebook is a record for other people to reproduce your work" (p. 8, transcript). This perception is in turn confirmed by looking to an excerpt taken from the notebook itself:

> Another batch of the gold-doped materials were prepared at the same concentration as the original batch. For Batch #2, 53 ml of the gold solution in water was added to reaction mixture immediately. . . . The mixture was vortexed for 1 minute, and passed through a syringe into

> the centrifuge head. The sample was immediately started spinning. A preliminary test of the mixture found the LCE matrix . . . formed an emulsion that did not phase separate for approximately 5 minutes. The gold nanoparticles were sonicated for 10 minutes before using. Then added directly to the reaction mixture.

The language Dave uses in his notebook objectifies laboratory activity by placing emphasis on objects (e.g., "materials," "solution") and actions ("was prepared," "was added"). The use of passive sentence constructions is indeed characteristic of his writing style in the notebook. As the above excerpt indicates, Dave himself is nowhere to be found; in his place are mixtures that are "vortexed" and samples that were started spinning. This in turn places a potential reader—including the scientist—in a position to replicate specific procedures either to obtain the "same" results or, conversely, to check those results against other methods and procedures for obtaining them. The notebook genre, I would argue, thus structures social action (see Miller, 1984) in two relevant ways: first, for the scientist who produces it, and second, for a potential reader who may eventually use it in his or her own work.

For Dave in particular, the notebook functions as a discursive (and non-discursive) space for recording procedures and for determining whether an expected outcome has been achieved. Yet he also deploys specific techniques in the laboratory, for instance TLC, in order to verify whether material samples have synthesized properly. This, he told me in an interview, is one of his primary objectives as a chemist working in the laboratory: "You want to make sure that what you say [the material] is is what it is" (transcript, p. 2). Although somewhat abstract on the face of it, Dave's statement aptly describes a common part of laboratory life. As Latour (1987, 1999) has shown, inscriptions tend to draw a scientist's attention away from the phenomena under investigation, but, in doing so, enable him or her to achieve a greater understanding of that phenomena. For Dave, TLC draws his attention away from the sample yet becomes a way to interpret, and thereby understand, the material in a more precise, methodical, and, ultimately, documentable way.

The TLC technique is fairly typical in chemists' work and involves adding a synthesized compound to the TLC plate and examining the way it separates. The TLC plates in turn become part of the textual record that Dave creates through his notebook. As a way to understand this process, I interviewed Dave and asked specific questions related to TLC and the TLC plates found in his notebook. This method helped me to trace the relationship between technical work enacted in the laboratory and textual documentation of that work. Dave describes the procedure as follows:

Dave: So . . . you have a thin layer of sand, but it's not actually sand; it's very small silicone-oxide particles glued to a surface, metal, or glass. And if you put a small drop of a chemical reaction at the bottom, and if you put it in, and then take that piece of paper—it basically looks like a piece of paper—and you put it in a jar with some solvents such as water, or in alcohol, or Toluene, or gasoline, or something. . . . Basically it will migrate on the surface of it. . . . And, different chemicals will migrate at different rates. So as you go along, you can see is, do I have two, three, or four different chemicals in my mixture, or do I have just one chemical? And you can also identify which chemical is which using the TLC plates. So if you imagine [. . .] you want to make some chemical, and you have these two starting materials that you want to connect together, and then you have your product. So on a TLC plate—let's say it's a 1-inch-wide TLC plate—you put a tiny drop of the one starting material on the left-hand side, a tiny drop of the other material on the right-hand side, and then hopefully your product in between them.

CW: Product is what?

Dave: The final reaction. So you mix the two together, you're hoping to connect A and B together to make C, so A is on the left-hand side, B is on the right-hand side, and hopefully C is in the middle. Then you put this in a development chamber, and the things migrate up the surface of the TLC plate, and hopefully that chemical A on the left-hand side will go one quarter of the way up, chemical C [sic: meaning B] will go, let's say, three quarters of the way up, and your final product, you hope, maybe, and this isn't always the case, will be in the middle half way up. And you can also see, OK, if everything's gone perfectly, in the middle, all of chemical A and all of chemical B are reacted so you won't see any of chemical A or chemical B left because they have been consumed, just like the gas in the car is consumed: You have an empty tank. But if the reaction has not run completely, then you can see if there is some leftover A, or leftover B, and that will also show up. So that's a quick—it takes about 5 minutes to do—it's a quick check to see if your reaction is going or not. And that's what chemists commonly use.

Figures 3 (A & B) illustrate a real-time process of Dave enacting the TLC technique. Figure 3 begins with Dave marking on the plate (Figure 3A) with a stylus so he can track the progress of the chemical that he is shown applying in Figure 3B. This procedure constitutes part of Dave's literate performance: an act that involves inscribing on the plate and then interpreting,

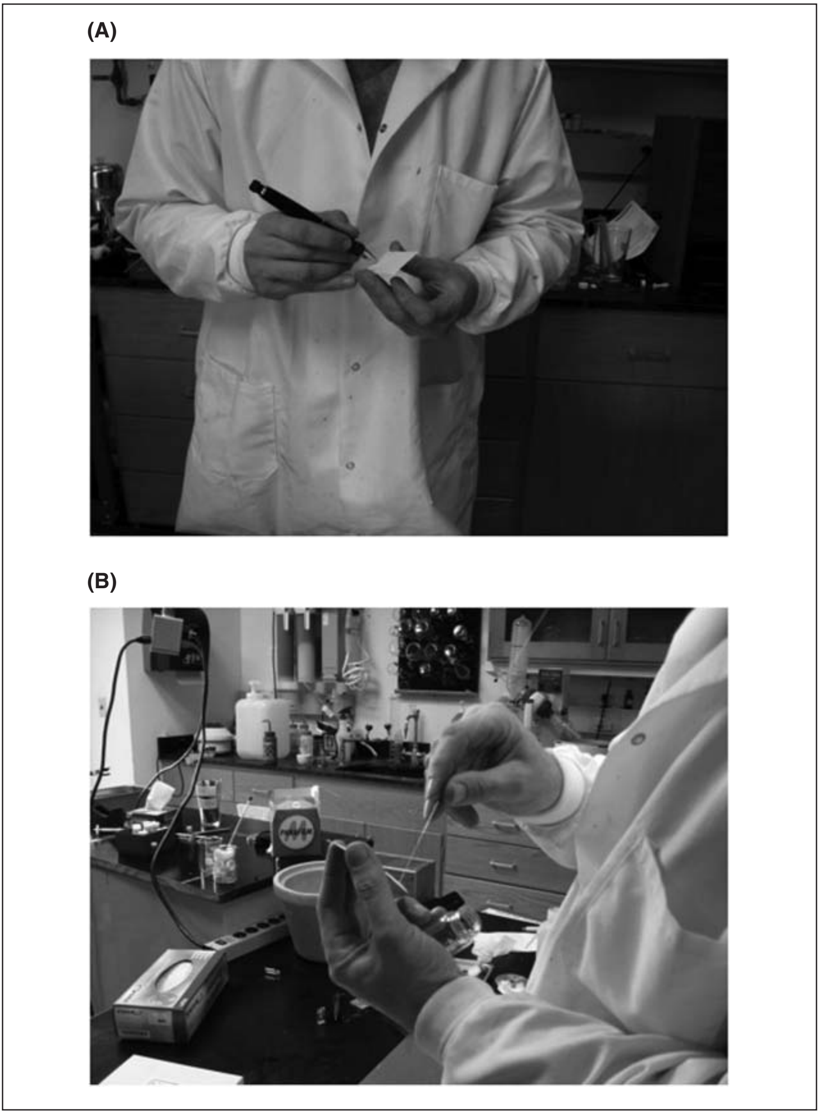

Figure 3. Dave marking thin-layer chromatography plate (A) and applying chemical (B)

or reading, the plate, once the reaction has taken place. The *reading* in this case is a highly trained skill that few people outside the scientific community would be able to understand. Yet for Dave, it is fundamental to his work as a chemist, that is, conceptualizing the relationship between materials and the techniques he deploys to determine that the synthesis has been successful and that he has a verifiable and thus usable material sample.

In situ interpretation of the TLC plate, however, is only part of the process through which Dave determines that a material synthesis has been successful. Indeed, the TLC plate also gets integrated into the notebook where it becomes part of a more complex textual assemblage (see Figure 4). This also was a topic of discussion in the interview:

CW: I noticed that you put some of these actual plates into your notebook.
Dave: They're for reference also.
CW: And again, will you just say briefly, what do they reference?
Dave: Just how well your reaction has run.
CW: OK, so, the product, you're saying, would you call that a sample?
Dave: It's what you're trying to make for a given reaction. So let's say you're trying, for example, you're trying to make pancakes in the morning. First you take your Bisquick, and you mix it with milk, and you mix it with an egg. And then you mix them all together with your blender. That might be the first stage of the reaction. And then when you're done you cook them and you have your final product, which is your finished pancake. So in the same way you take chemicals A, B, and C, you throw them together, and you hope they combine in some way. But you can't see the outcome because it's too small to see by the human eye, so you use these different techniques like the spectroscopy, or the TLC plates, to visualize that everything is mixed and made what you want properly.

Several points can be taken from this excerpt. First, TLC enables Dave to engage with material samples and interpret their content. Such techniques are necessary in the sense that their visual outputs enable him to analyze what he cannot observe with naked eye. This in itself suggests that inscriptions are a constructive part of his work. More precisely, the TLC plate helps Dave construct an immediate image of the material he has synthesized, yet the plate is also constructive in the sense that it gets integrated into the notebook where it can be interpreted in light of the procedural steps he has recorded in that space (see Figure 5). This is not to suggest that the work of science is like any other interpretive process; it is to suggest, however, that scientists themselves are adept at creating and using tools—paper, otherwise—which enable them to probe various dimensions of the material artifacts they produce and study in their work (see Klein, 2001).

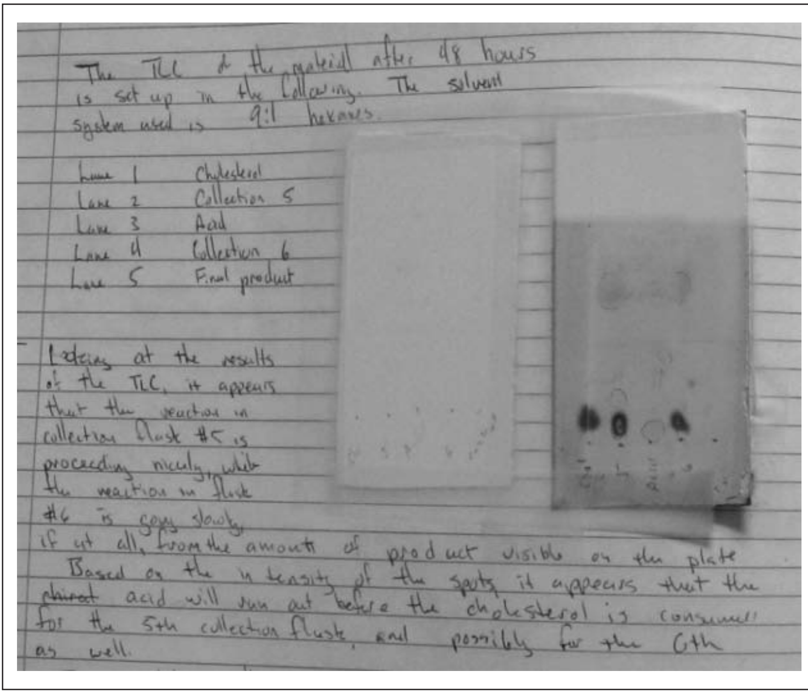

Figure 4.

The interpretive nature of this process is reflected in the language he uses to document it. Consider an excerpt from his notebook where the TLC procedure and the TLC plate becomes part of the textual record:

> Looking at the results of the TLC, it appears that the reaction in the Collection Flask #5 is proceeding nicely, while the reaction in Flask #6 is going slowly, if at all, from the amounts of product visible on the plate. Based on the intensity of the spots, it appears that the acid will run out before the cholesterol is consumed for the fifth collection flask, and possibly for the sixth as well.

The TLC plate in this case is not a guarantor of success. Indeed, words like “appears” and “possible,” and phrases like “if at all,” suggest that the plate is a means through which Dave can evaluate whether and the extent to which success has been achieved. The plate does of course reveal necessary details about the sample’s content, but the result—what Dave reads—is less the

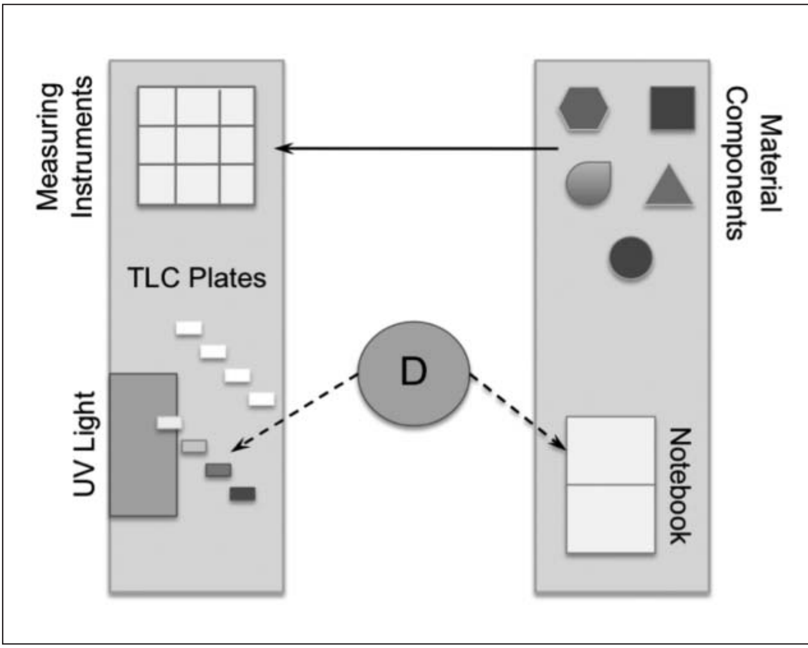

Figure 5. Dave's (D) research space, context of TLC and notebook integration—top view

sample per se than it is a dynamic relationship between the chemicals, the plate, and his experience that tells him how to interpret what he perceives. That interpretation is then qualified through the other resources that get assembled in the notebook—resources that contribute to the holistic account he creates over time. Yet it is the TLC plate, alone, that (quite literally) enables Dave to transform the materiality of laboratory practice into a documentable inscription that in turn does textual work when integrated with other semiotic modes—for example, linguistic script, chemical structures—deployed in the same graphic space (see Table 3).

Consider a typical page from Dave's notebook (Figure 6). A simple (or not-so-simple) description would reveal a number of semiotic resources he deploys as part of his documentation practices. It would include, from top left, linguistic script in the form of the notebook font; handwritten linguistic script; chemical structures; a list of starting materials, compounds, and procedures; a TLC plate; and more handwritten linguistic script that contextualizes the plate. Not every one of these resources has a "life of its own" outside

Table 3. Inscriptions and Semiotic Modes by Role in Task, Relation to Material, and Textual Affordance

Descriptor	Role in laboratory	Relation to material
Thin-layer chromatography plates	Product of procedure; taped into notebook.	Communicates interpretation of material output.
Linguistic script (alpha numeric)	Document procedures, integrate inscriptions textually in notebook, label materials.	Communicates findings holistically on the basis of *in situ* interpretation of laboratory phenomena.
Chemical structures	Visualize materials used and produced; taped and hand drawn in notebook.	Communicates structure of raw materials as input.
Graphs (visual displays)	Product of analysis; taped into and hand drawn in notebook.	Communicates outcome of synthesis.
Diagrams	Portray methods, procedures, objects; hand drawn in notebook.	Communicates methods of materials production.
Photographic images	Visually record procedures and results; taped into notebook.	Communicates input and output of materials production.
Formulas	Analyze materials used and produced; taped and handwritten into notebook.	Communicates structure of raw materials as input.
Visual spectra	Product of procedure; taped into notebook.	Communicates interpretation for material output.

the notebook in the way that the TLC plate does. Even so, they function together as an ensemble where meaning is realized through but is greater than the sum of its parts (see Hull & Nelson, 2005). Said another way, meaning is generated not simply through a closed system; it is also generated via production techniques (e.g., the TLC) and the ways in which the output of those techniques (e.g., a TLC plate) become part of a distributed process of text production that draws upon any number of resources.

Linguistic script is a key part of this process. Most obvious, perhaps, is the way in which it *integrates* the other semiotic modes and inscriptions that occupy a shared graphic space (see Harris, 1995, 2000). For instance, Dave includes a printout of the procedures through which he synthesized the raw materials involved in his work. This step-by-step rendering provides a

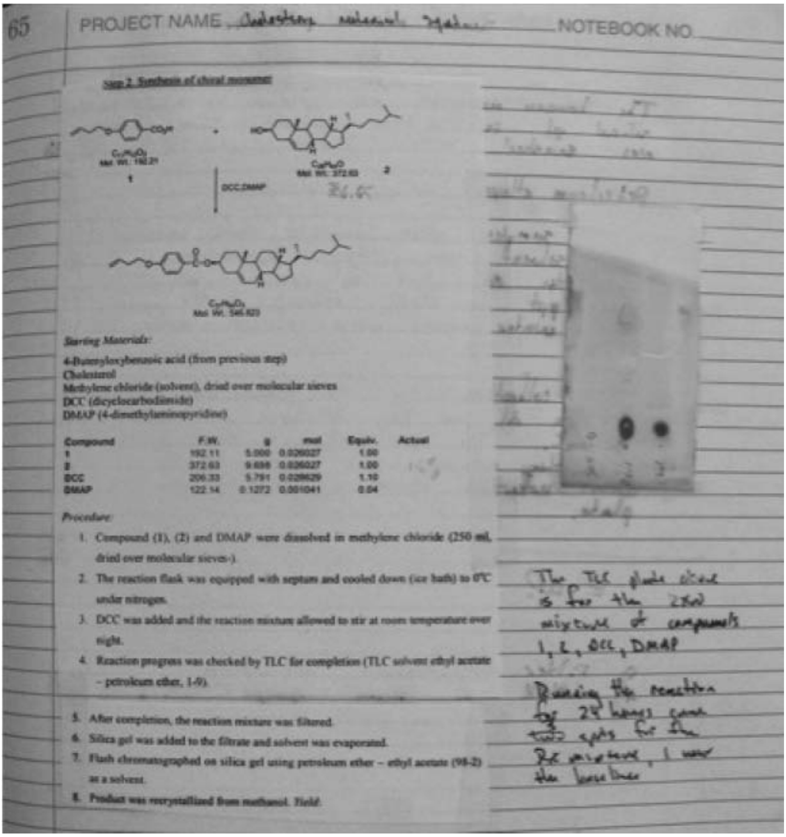

Figure 6.

durable means for explaining the activity itself—thus legitimizing it through the method—and also for contextualizing other semiotic modalities on the page. Compare this with the chemical structures pictured near the top of the page. This mode of representation ostensibly has a direct relationship to the material itself and visualizes how different substances might synthesize under particular conditions. Representing those structures linguistically is possible but would be less efficient than rendering them as a visual structure in the sense that a linguistic description would take up more space, take more time, and may not provide as useful or immediate an image as the conventionalized structures themselves. Each semiotic resource, then, affords something for the task at hand. In this case, the chemical structures provide a means to visualize the materials—and how they might synthesize—at a molecular level; the linguistic script, however, complements this visualization through a more descriptive record of the procedures undertaken in the actual synthesis.

Once Dave gets to the procedures, he returns to linguistic script and forms a list. (He uses a different medium here as well. Print documents function, he says, to keep his notes clean.) Though perhaps an obvious move, it further supports a concept of semiotic affordance. As Dave said in his interview, "The idea of the lab notebook is . . . supposed to be that, if I were to die tomorrow, meet my untimely demise, someone should be able to use the lab notebook to repeat my work" (p. 4, transcript). This candid assessment means, in part, that information must be durable in the sense that someone else can read, and, over time and space, understand specific procedures to the point that they can be replicated and tested. Visual modalities—for example, chemical structures—might prove useful for Dave but do not in themselves contextualize procedures in the way that linguistic text can. Such visuals do, of course, contribute to the overall textual meaning: In this case, the visual structure illustrates what one can expect to happen at a molecular level once the procedure has been undertaken. This affordance in turn enables Dave, or any trained reader, to link the "known"—for example, the starting materials and procedures—with other "knowns"—for example, the TLC plate—which lead to an overall rendering of the production process and its material outcomes.

In addition to the procedural documentation, which shows the materials used, how they were synthesized, and the techniques to which they were submitted, Dave includes the TLC plate as evidence of the technique itself. The TLC plate in this way is operating at multiple representational levels at once. First, it represents a conventional process whereby materials are characterized in the laboratory; second, it represents the product of that characterization that is both a means of testing and a textual inscription; third, as an inscription, it integrates with other semiotic modalities in the text—in this case, the chemical structures, the linguistic procedures, and so on—to create a holistic record of laboratory activity. This is a key connection between the notebook, as text, and the technique of TLC: the inscription used to characterize a sample in time and space becomes part of an ensemble where that time and space is rendered textually as a way to confirm that the sample is what Dave, and any other potential reader, expects it to be.

The notebook thus functions in at least two significant ways for Dave. First, it is a means for documenting technical procedures. This occurs through

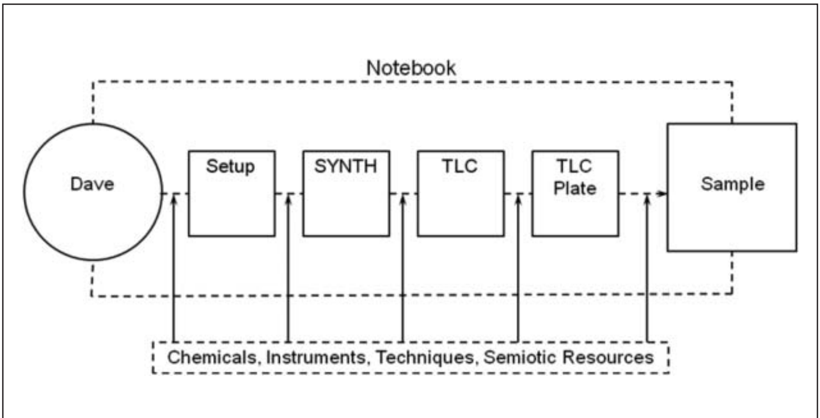

Figure 7. Model of material and text production

multiple semiotic resources, some of which are the direct result of material processes in the laboratory—for example, the TLC plate—and some of which are added into the notebook directly as a way to contextualize those procedures, and their outcomes, in relation to the overall process of material production. Second, the notebook, once produced, becomes both a resource for future research and a means whereby Dave can show that has produced a legitimate material sample. More precisely, once he has produced a sample, and once he has documented that process textually, he has two resources for confirming that he has done "good" work. The sample, on the one hand, constitutes the material output that can be taken up by physicists and further characterized through their experimental systems; the notebook, on the other hand, constitutes a durable textual resource that can be used by chemists or physicists either to confirm existing samples as epistemic objects or to produce more samples on the basis of replicable procedures.

Figure 7 provides a simple model that helps to illustrate these relationships. On the left is Dave, a scientist, and on his right are procedures involved in preparing, synthesizing, and verifying the sample as a material and epistemic outcome of his technical work. These procedures are in turn facilitated by the chemicals, instruments, techniques, and semiotic resources that are available to him and that he actively deploys through each step of his inquiry. As depicted, the notebook underlies the whole of this process: It is a background trace that is constantly produced and revised but that always informs Dave's research. The notebook in this way gives context to his work—as a durable record of his research activity—and thus provides a resource for confirming the validity of his procedures and the sample he has produced. Yet it also constrains, or disciplines, his work in the sense that it is a dynamic reference that he can consult at any stage in his research in order to deliberate about how best to proceed. Though this model simplifies a highly complex process, it does begin to show the intimate relationship between material and text production in this laboratory setting.

Discussion and Implications

Examining the relationship between Dave, his notebook, and the practice of material production illustrates the extent to which texts shape meaning making, communication, and knowledge production in a modern scientific workplace. Medway's (1996) work helps to elucidate this relationship. The architects in his study bring new conceptual realities into the world prior to the physical structures their designs would help to construct. The scientist in my study, however, performs something of an inverse move; that is, he literally brings new materials into the world—ones that do not occur in nature—while confirming their material and conceptual "reality" through a series of technical procedures and textual documentation practices. Although Dave's notebook does function as something of a "blueprint" for creating material samples, it is much more than a set of procedural guidelines. Indeed, it is a dynamic text that is produced in tandem with technical procedures. Examining how the technical and the textual are connected through the TLC plate, I have shown how this scientist visualizes, interprets, and ultimately renders his work into a durable resource for himself and others. This process suggests that technical work and textual documentation are mutually constitutive and that notebooks, therefore, help to construct rather than simply report scientific research findings. Scientific writing, in this way, may be best understood by looking not only at the texts scientists produce but also at the way those texts are implicated in the technical and knowledge-productive work they perform.

Witte's constructivist semiotic, as discussed earlier, offers a useful basis for further elaborating the theoretical implications of this investigation. Specifically, his concept of *intertext* suggests how the notebook, as a laboratory resource and genre-specific mode of disciplinary communication, integrates Dave's knowledge of chemistry with the technical and rhetorical work he must perform to undertake and report on his research. As Witte (1992) suggests:

> When texts . . . are used or read by their writers, the metaphorical space between the contexts of production and use is relatively small and the

> intertext(s) that shape and are shaped through the text-context(s) relation would seem more or less predictable. But anytime a reader who is not the writer enters the picture, the metaphorical space between production and use widens, and the influence of alternate intertexts on the constructive processes increases dramatically. (p. 287)

Here, Witte theorizes the concept of *intertext* as a way to explain the connections between individual writers or groups of writers, their projected audience(s), and the various interpretations that may be brought to bear on the text(s) in question. "In such cases," he continues, "writing and reading become processes of negotiating the intellectual and emotional space between the 'self' and the 'other', between the individual and the social, as the multiple voices of distinct constructive semioses mix on what might be called the battlefield of the 'trace'" (p. 287). When situating notebooks in laboratory practice, this theorizing of *intertext* is applicable in a very material way; that is, it helps me, as a researcher, to investigate and articulate the convergence of Dave's technical work (e.g., synthesizing materials), interpretive work (e.g., TLC), and rhetorical work (e.g., integrating TLC plates alongside various other inscriptions in the notebook so as to communicate research findings to an anticipated audience).

TLC plates, understood via Witte's theory of intertext, constitute what I would call an "intertextual reference" that enables Dave both to interpret *in situ* chemical processes and to document his interpretations in a notebook. The notebook in turn enables him to stabilize his interpretations, and thus the reference in question, insofar as it provides a space within which to holistically represent the procedural input and material output of his research. This happens not just through TLC plates, of course, but also through the multiple semiotic resources that Dave integrates into the same graphic space. The notebook becomes constructive, then, in the ways I suggest in the introduction to this article: (1) it is a physical space that draws together various inscriptions and semiotic modes; (2) it is a conceptual space that provides Dave with an image of chemical processes that he cannot perceive directly; and (3) it is a rhetorical space through which laboratory practice is transformed into a durable communal resource that, in theory at least, limits the range of intertextual interpretations that can be brought to bear on the material output of Dave's work. More precisely, the notebook, as a recognizable genre, helps to close the metaphorical gap between production and use insofar as it disciplines how inscriptions, like TLC plates, are read in light of the other resources that Dave deploys to represent and communicate his research.

Findings from this study can complement existing research in several ways. Investigating the role of notebooks in a modern scientific workplace, for instance, extends studies that have examined this genre of writing as part of broader projects related to invention and discovery in the history of science. This scholarship has demonstrated the ways in which scientists use writing, and notebooks in particular, not only as a means to document or communicate their work but also to negotiate the material and social constraints that shape the very conduct of their inquiry. My study adds to this body of research by showing how one scientist actually deals with those constraints in the context of his day-to-day laboratory practice. Exploring real-time processes, I would argue, specifically offers a useful dimension to existing scholarship insofar as it illustrates the choices scientists make when dealing with the materiality of their research and their writing—and how, through the notebook, the material, technical, and symbolic converge in complex and knowledge-productive ways.

Examining notebook production and use also extends research that has explored the material dimensions of *in situ* writing activity. As scholars like Medway (1996) and Haas and Witte (2001) have shown, writers often draw upon a variety of resources—from architectural drawings to gestures—when producing documents that respond to workplace exigencies. These resources vary across writing tasks but invariably contribute to the ways in which writers construct texts, and, to some extent, the material realities those texts are designed to represent. The writing materials discussed in this article—for example, the notebook and the inscriptions and semiotic modes through which it is assembled—likewise constitute resources through which Dave is able to construct a durable record of his laboratory work. Yet the resources themselves, and the TLC plate in particular, insofar as they are materially linked to the phenomena being investigated, provide more than a textual means of documenting technical procedures. Indeed, they quite literally bring the materiality of laboratory practice into the text where it is rendered into verifiable scientific knowledge. Understanding this as *writing* process is a positive move to account for the relationship between technical work, textual documentation, and the ways in which material reality is negotiated and constructed semiotically as much as it is realized through a closed system of signification.

Situating multimodal texts like the laboratory notebook in the context of scientific practice contributes as well to research that focuses on texts alone as units of analysis. Analytical frameworks developed by Kress (2000, 2003) and others (see Baldry & Thibault, 2006; Kress & van Leeuwen, 1996, 2001; Lemke, 1998) do provide useful and necessary insight into the ways in which meaning is realized and communicated through multiple semiotic modes, yet a focus on texts without a focus on the practices in which they are embedded, and through which they are produced, offers only partial insight into the meaning(s) they convey. Consider once again the TLC plate that Dave produces in the laboratory and integrates into his notebook. Examining this inscription textually suggests what three-dimensional objects generally afford for documenting the procedures involved in materials production. What such analyses do not necessarily uncover, however, are the complex processes through which such inscriptions are produced, and, thus, how they can be interpreted in light of the broader tasks and practices in which they are deployed in the field of chemistry. Accounting for the representational choices scientists make *in situ* ultimately adds an important layer to the way scientific writing and text production gets theorized both for teaching and research purposes.

Finally, examining multimodal text production in a scientific setting highlights the specific exigencies to which texts respond and the symbolic resources that writers deploy to address those exigencies. This focus is important in the sense that scientific writing often involves the "accommodation" (see Fahnestock, 1986) of information to different audiences. How scholars of writing understand this accommodation—and potentially help facilitate it—relies to a great extent on how we understand the modes through which it takes place and what those modes afford for the people using them to construct and disseminate knowledge. Likewise, how nonexperts in general perceive and understand technical and scientific information relies to a great extent on the ways in which they understand not just content per se but also how that content is shaped by the modes through which it is constructed and communicated. Moving beyond an explicit focus on linguistic discourse, as I have attempted to do in this article, ultimately helps to account for the range of signification practices that expert scientists deploy in their work, and, thus, the ways in which technical and scientific information can be communicated efficiently and well.

Declaration of Conflicting Interests

The author(s) declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research and/or authorship of this article.

Notes

1. More broadly, notebooks constitute just part of a dense network of texts and writing practices involved in the conduct and communication scientific inquiry. Ethnographies of "laboratory life" have surveyed some of this ground through close analyses of scientists' *in situ* representational practices (Knorr-Cetina, 1981, 1999; Latour, 1987, 1999; Latour & Woolgar, 1979/1986; Lynch, 1985; Traweek, 1988; see also Lynch & Woolgar, 1988). As these scholars have shown, writing is instrumental to the ways in which scientists visualize their work, make it available for intersubjective deliberation, and ultimately sort through the "mangle of practice" that is laboratory research (see Pickering, 1995, p. 23). This body of research, I would argue, confirms what scholars have found through historical and archival investigations, namely, that scientists use texts like notebooks to transform the materiality of laboratory practice into durable communal knowledge. Yet these studies, revealing though they are, tend to focus on written inscription as a means to characterize science as a cultural practice—and not, per se, to explore scientific texts with the intent to theorize writing as a situated rhetorical activity. My aim in this article, conversely, is to articulate a concept of writing in science that is coextensive with the material, symbolic, and technological resources that scientists deploy in their meaning making and textual communication (see Kozma, Chin, Russell, & Marx, 2000).
2. Following Witte (1992; see also Winsor, 1994), I define *texts* as "organized sets of symbols or signs" (p. 137). This is a broad view that accounts well for the types of writing—linguistic and nonlinguistic alike—which scientists use and produce in their work.
3. I obtained permission through the university institutional review board and from scientists themselves to undertake this research. Names have been changed to protect participants' anonymity.
4. For the sake of analysis, I differentiate between text and inscription on the basis that texts are genre-specific ways of presenting information that may include many inscriptions. I use the term *inscription*, following Latour (1987, 1988), to encompass representations that are produced through a scientific instrument or technique in the laboratory. I further differentiate between *inscription* and *semiotic mode* on the basis that modes are culturally recognizable channels through which meaning is realized textually, for example, linguistic script, schematics, photographic images, illustrations, and so on (see Kress & van Leeuwen, 1996, 2001). Whereas inscriptions, I will show, get "assembled" into texts, semiotic modes act as a means by which scientists contextualize inscriptions as part of specific procedures and outcomes. Finally, I use the term *semiotic resource* as an umbrella term to include both inscription and mode.

5. Unless noted otherwise, “materials” in this context refer to synthesized chemical compounds that do not occur naturally and that serve as “samples” for research. These may include anything from cholesteric liquid crystals to gold nanorods to liquid-crystal elastomers. A “sample” is typically understood as a known quantity of some material that can be characterized through controlled experimentation.
6. Rheinberger defines epistemic objects as “the material entities or processes—physical structures, chemical reactions, biological functions—that constitute [scientific] objects of inquiry” (p. 28). I use this term to suggest that material samples are warranted as knowledge in the notebook through the convergence of technical procedures and textual documentation practices.
7. As part of my agreement with these scientists, I was not able to record talk in the laboratory. This method has, however, proven generative in ethnomethodological studies of laboratory work (e.g., Lynch, 1985).

References

Ackerman, J., & Oates, S. (1996). Image, text, and power in architectural design and workplace writing. In A. H. Duin & C. J. Hansen (Eds.), *Nonacademic writing: Social theory and technology* (pp. 81-121). Mahwah, NJ: Lawrence Erlbaum.

Bezemer, J., & Kress, G. (2008) Writing in multimodal texts: A social semiotic account of designs for learning. *Written Communication, 25*, 166-195.

Baldry, A., & Thibault, P. (2006). *Multimodal transcription and text analysis*. London: Equinox.

Bakhtin, M. M. (1981). Discourse in the novel. In M. Holquist (Ed.), *The dialogic imagination: Four essays by M. M. Bakhtin* (C. Emerson & M. Holquist, Trans., pp. 259-422). Austin: University of Texas Press. (Original work published 1935)

Bazerman, C. (1988). *Shaping written knowledge: The genre and activity of the experimental article in science*. Madison: University of Wisconsin Press.

Bazerman, C. (1999). *The languages of Edison’s light*. Cambridge: MIT Press.

Bracewell, R. J., & Witte, S. P. (2003). Tasks, ensembles, and activity: Linkages between text production and situation of use in the workplace. *Written Communication, 20*, 511-59.

Campbell, J. A. (1990). Scientific discovery and rhetorical invention: The path to Darwin’s *Origin*. In H. W. Simons (Ed.), *The rhetorical turn: Invention and persuasion in the conduct of inquiry* (pp. 58-90). Chicago: University of Chicago Press.

Chin, E. (1994). Redefining “context” in research on writing. *Written Communication, 11*, 445-482.

Collings, P. J. (2002). *Liquid crystals: Nature’s delicate phase of matter*. Princeton, NJ: Princeton University Press.

Crick, N. (2005). “A capital and a novel argument”: Charles Darwin’s notebooks and the productivity of rhetorical consciousness. *Quarterly Journal of Speech, 91*, 337-364.

Dias, P., Freedman, A., Medway, P., & Paré, A. (1999). *Worlds apart: Acting and writing in academic and workplace contexts.* Mahwah, NJ: Lawrence Erlbaum.

Fahnestock, Jeanne. (1986). Accommodating science: The rhetorical life of scientific facts. *Written Communication, 3*, 275-296.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory*. Hawthorne, NY: Aldine.

Gooding, D. (1989). “Magnetic curves” and the magnetic field: Experimentation and representation in the history of a theory. In D. Gooding, T. Pinch, S. Schaeffer, & T. Pinch (Eds.), *The uses of experiment: Studies in the natural sciences* (pp. 183-224). Cambridge, UK: Cambridge University Press.

Gooding, D. (1990a). Mapping experiment as a learning process: How the first electromagnetic motor was invented. *Science, Technology, & Human Values, 15*, 165-201.

Gooding, D. (1990b). *Experiment and the making of meaning: Human agency in scientific observation and experiment*. Dordrecht, Netherlands: Kluwer.

Gross, A. G. (2006). *Starring the text: The place of rhetoric in science studies*. Carbondale: Southern Illinois University Press.

Gruber, H. E. (1974). *Darwin on man: A psychological study of scientific creativity*. New York: E. P. Dutton.

Haas, C., & Witte, S. P. (2001). Writing as embodied practice: The case of engineering standards. *Journal of Business and Technical Writing, 15*, 413-57.

Harris, R. (1995). *Signs of writing*. London: Routledge.

Harris, R. (2000). *Rethinking writing*. New York: Continuum.

Holmes, F. L. (1984). Lavoisier and Krebs: The individual scientists in the near and deeper past. *Isis, 75*, 131-142.

Holmes, F. L. (1985). *Lavoisier and the chemistry of life: An exploration of scientific creativity*. Madison: University of Wisconsin Press.

Holmes, F. L. (1987). Scientific writing and scientific discovery. *Isis, 78*, 220-235.

Holmes, F. L. (1990). Laboratory notebooks: Can the daily record illuminate the broader picture? *Proceedings of the American Philosophical Society, 134*, 349-366.

Holmes, F. L. (2004). *Investigating pathways: Patterns and stages in the careers of experimental scientists*. New Haven, CT: Yale University Press.

Holmes, F. L., Renn, J., & Rheinberger, H-J. (2003). *Reworking the bench: Research notebooks in the history of science*. Dordrecht, Netherlands: Kluwer.

Hull, G., & Nelson, M. E. (2005). Locating the semiotic power of multimodality. *Written Communication, 22*, 224-61.

Klein, U. (2001). *Tools and modes of representation in the laboratory sciences*. Dordrecht, Netherlands: Kluwer.

Knorr-Cetina, K. (1981). *The manufacture of knowledge: An essay on the constructivist and contextual nature of science*. New York: Pergamon Press.

Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

Kozma, R., Chin, E., Russell, J., & Marx, N. (2000). The roles of representations and tools in the chemistry laboratory and their implications for chemistry learning. *The Journal of the Learning Sciences, 9*, 105-143.

Kress, G. (2000). Multimodality. In B. Cope & M. Kalantzis (Eds.), *Multiliteracies: Learning and the design of social futures* (pp. 182-202). London: Routledge.

Kress, G. (2003). *Literacy in the new media age*. London: Routledge.

Kress, G., & van Leeuwen, T. (1996). *Reading images: The grammar of visual design*. London: Routledge.

Kress, G., & van Leeuwen, T. (2001). *Multimodal discourse: The modes and media of contemporary communication*. New York: Oxford University Press.

Kristeva. J. (1986). Word, dialogue, and novel. In T. Moi (Ed.), *The Kristeva reader* (T. Gora, A. Jardine, & L. S. Roudiez, Trans., pp. 34-61). Oxford, UK: Basil Blackwell. (Original work published 1969)

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society.* Cambridge, MA: Harvard University Press.

Latour, B. (1988). Drawing things together. In M. Lynch & S. Woolgar (Eds.), *Representation in scientific practice* (pp. 19-69). Cambridge: MIT Press.

Latour, B., & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts*. Princeton, NJ: Princeton University Press. (Original work published 1979).

Lemke, J. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. R. Martin & R. Veel (Eds.), *Reading science: Critical and functional perspectives on discourses of science* (pp. 87-113). London: Routledge.

Lynch, M. (1985b). *Art and artifact in laboratory science: A study of shop work and shop talk in a research laboratory.* London: Routledge and Kegan Paul.

Lynch, M., & Woolgar, S. (Eds.). (1988). *Representation in scientific practice*. Cambridge: MIT Press.

Medway, P. (1996). Virtual and material buildings: Construction and constructionism in architecture and writing. *Written Communication, 13*, 473-514.

Medway, P. (2002). Fuzzy genres and community identities: The case of architecture students' sketchbooks. In R. Coe, L. Lingard, & T. Teslenko (Eds.), *The rhetoric and ideology of genre: Strategies for stability and change* (pp. 123-153). Cresskill, NJ: Hampton.

Miller, C. (1984). Genre as social action. *Quarterly Journal of Speech, 70*, 151-176.

Palffy-Muhoray, P. (2007). The diverse world of liquid crystals. *Physics Today, 60*, 54-60.

Prior, P. (1998). *Writing/disciplinarity: A sociohistoric account of literate activity in the academy*. Mahwah, NJ: Lawrence Erlbaum.

Rheinberger, H. J. (1997). *Toward a history of epistemic things: Synthesizing proteins in the test tube*. Stanford, CA: Stanford University Press.

Smagorinsky, P., Zoss, M., & Reed, P. (2006). Residential interior design as complex composition: A case study of a high school senior's composing process. *Written Communication, 23*, 295-330.

Strauss, A. L. (1987). *Qualitative analysis for social scientists*. Cambridge, UK: Cambridge University Press.

Tweney, R. D. (1991). Faraday's notebooks: The active organization of creative science. *Physics Education, 26*, 301-306.

Tweney, R. D., & Gooding, D. (1991). *Michael Faraday's "chemical notes, hints, suggestions, and objects of pursuit" of 1822.* London: Short Run Press.

Winsor, D. (1994). Invention and writing in technical work: Representing the object. *Written Communication, 11*, 227-250.

Witte, S. (1992). Text, context, intertext: Toward a constructivist semiotic of writing. *Written Communication, 9*, 237-308.

Bio

Chad Wickman, PhD, is an assistant professor of technical and professional communication at Auburn University. He received his doctorate in English (literacy, rhetoric, and social practice) from Kent State University. His current research explores the material, technical, and symbolic dimensions of writing and representation in the physical sciences.