Engineering Writing/Writing Engineering

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Knowledge is not found ready-made in nature. Instead, knowledge is constructed in the interplay between nature and the symbol systems we use to structure and interpret it. (See Bazerman, *Shaping Written Knowledge,* 291–317, for a discussion of the way nature and the statements we make about it limit one another.) Over the last ten years, this notion of the construction of knowledge has become increasingly accepted by those of us in the humanities and social sciences. We talk, therefore, of language, and particularly written language, as a tool for constructing ideas, of a given field of knowledge being created by the interaction of its practitioners' texts, and of knowledge itself, including scientific knowledge, as rhetorically shaped. (See, for instance, Lefevre; Bruffee; Nelson et al.; and Latour, *Science in Action.*)

We accept the idea that our knowledge is shaped by our language. But this view of language and writing is not necessarily accepted in other parts of our campuses, as those of us who teach engineers, for example, can attest. Engineering defines itself as a field concerned with the production of useful objects. In keeping with this concern, engineers tend not only to see their own knowledge as coming directly from physical reality without textual mediation, but also to devalue the texts engineers themselves produce, seeing them as simple write-ups of information found elsewhere.

Scholars and teachers of technical writing have, to some degree, tended to share this view. Several of our most significant studies of engineers' writing, for instance, examine the way writing is used to transmit engineering knowledge rather than to generate it (Allen; Paradis et al.; Broadhead and Freed). Technical writing textbooks, too, often present writing solely as a means to report on what the engineer already knows. Mathes and Stevenson's influential *Designing Technical Reports,* for instance, enjoins the engineer to shift out of a technical mode and into a report writing mode when getting ready to write (3–8). Writing is viewed as part of an engineer's job but not as part of engineering, which presumably happens in some separate, prior realm (cf. An-

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derson 3–6; Houp and Pearsall 8–9; Lannon 8). Insofar, however, as engineering is knowledge about objects and how to build them rather than the actual building itself, it is necessarily a symbol-bound field. That is, even this field, which seems so tied to physical reality, is necessarily accomplished through language.

While our theory says, then, that engineering, like all knowledge, is filtered through language, studies have not yet shown how engineers' writing would look when contemporary views about the textual shaping of knowledge are applied. This paper is an attempt to fill that gap. The basis for this paper is (1) a file of engineering documents, (2) comments made on those documents by a mechanical engineer who had participated in the engineering activity they described, and (3) the engineer's own activity as he wrote a technical paper he later presented at a professional conference. The engineer, whom I will call John Phillips, had a Ph.D. in Mechanical Engineering. Phillips had about fifteen years of work experience and was a middle-level manager in the Research and Development department of a large manufacturing company. He had the file of documents because he was using them to write a paper to be presented at the national convention of the Society of Automotive Engineers. His paper described his research group's efforts to lower an engine's emissions in order to meet new standards issued by the Environmental Protection Agency. Phillips anticipated that other researchers would find the information useful in working toward lowering their own engines' emissions, although his results would have to be adapted by them to suit their own engines' different configurations. Examination of the texts Phillips used and the one he produced suggests the way engineers write both their knowledge and themselves.

Writing Engineering Knowledge

Textual mediation of knowledge is difficult for engineers to accept because they see themselves as working directly on physical objects. Examination of the documents Phillips was using, however, showed that most of the reports he had were based on written material more or less distant from lab results and that lab results themselves were writing. In the lab, engineers use instruments, which are materializations of previous knowledge, to translate physical objects into written data which can then be manipulated and studied. Some lab instruments, such as a spectrograph or computer, actually write directly on a piece of paper. Others, such as a temperature gauge, translate physical phenomena (such as heat) into a useful written form (such as numbers). As Karin D. Knorr says,

> In the laboratory, the "texts" are provided by constantly accumulated combinations of measurement traces (graphs, figures, printouts, diagrams, tables, etc.). (352)

These "texts" are then interpreted in order to become engineering knowledge. Numerous researchers have established the degree to which data fail to speak for themselves and are instead the subject of interpretation (see, for example, Knorr; Law and Williams; Latour, *Science in Action*). For the most part, this interpretation too is carried out in writing.

This reliance on writing has been shown to be present in the work of scientists. In *Laboratory Life,* their study of laboratory scientists, Bruno Latour and Steve Woolgar noticed the omnipresence of writing. Latour and Woolgar concluded that the objective of lab activity is inscription, the conversion of physical reality into written documents ranging from lists of numbers to published papers. Inscription can be seen as happening in a chain because, although documents are written as though they refer directly to physical reality, they actually refer to and are based on other documents. Documents produced later are valued as they are able to generalize the content of a larger number of earlier documents. For instance, a lab report giving pieces of specific data can be used, along with other such reports, to create a curve showing a trend. The curve can then be used to support a theoretical claim in a paper. Knowledge is thus constructed through texts, not discovered in the original process of lab work.

Moreover, the textual construction of knowledge is social in nature because each document must convince other people of its validity in order to be accepted as knowledge. Only documents that do convince others are used. Documents that for any reason cease to be convincing cease being treated as containing knowledge. Thus, for instance, twentieth-century scientists do not treat the contents of astrology texts as knowledge, although fourteenth-century scientists did. In effect, knowledge may be defined as that which most people in a discourse community are convinced of, and what a discourse community is convinced of is indicated by the texts it has accepted. (See Bazerman, "Scientific Writing," for a survey of research in the social construction of scientific knowledge. See Dobrin for a discussion of the relationship between objectivity and social construction.)

Engineers' Reliance on Writing

The phenomenon of inscribed knowledge, which Latour and Woolgar observed among scientists, is also seen in the engineering documents studied here. To some degree, this sameness is surprising because engineering differs from laboratory science in that it more immediately aims at practical application (cf. Miller, "Ethos"; Miller and Selzer). It is supposed to result in a physical product (in this case a low-polluting engine) whose success or failure in the marketplace is the measure of the engineer's work, as an influential, frequently-cited paper is of the scientist's. For the technologist, writing is a means to the end of producing an object. Knowledge is built for this end, rather than valued for itself. The engine, rather than a document, is "final publication" for the engineer. There is, therefore, a temptation to see engineering writing in the way engineers do, as incidental to the project at hand.

Examination of Phillips' work, however, reveals that, while for him writing is not the final product, it is an essential means by which that product is created because it is the essential means by which engineering knowledge is created. Thus, when Phillips sat down to write his paper, he did not begin by looking at the engine. For one thing, as a subject for a conference paper, the engine both existed too publicly and did not exist at all. It existed too publicly in that it was being produced, and other engine researchers could buy one and look at it directly, so they did not need the paper to know about the engine. (According to Phillips, however, it was unlikely competitors would look at the actual engine. They too would be most likely to consult a document—in this case certification reports filed with EPA—rather than the object.) The engine discussed in the paper did not exist at all in that the actual numbers for fuel economy, pollution, power, etc., reported in the paper came, not from engines actually being produced, but from engines set up in lab test cells. Those engines had long since been torn down and the cells devoted to other purposes. So the paper necessarily drew, not on contemporaneous physical lab results, but on results and analysis already written and interpreted in other documents.

In writing his own paper, Phillips used a file of documents written by other people in his workplace. The bulk of the documents he had were, in order of their production, data sheets, handouts from oral presentations, and what his company called Progress Reports and Technical Reports. Data sheets are computer-produced lists of numbers generated in a test cell. They are produced by placing a probe in the engine to measure a variable (for instance, nitrous-oxide emissions) and then changing a condition (for instance, temperature) in a controlled way. The computer records results at various points and prints them out in a list engineers analyze to determine their success or failure in meeting government-mandated emission standards. Data sheets were unique among the documents Phillips had because they were the only ones produced by looking directly at physical reality. Every document subsequent to them was produced by looking at least partly at other documents. Thus, the computer was the only "writer" here not writing from previous texts.

Though the computer writes directly from observation of an object, its writing is still socially shaped. First, the computer and its attached instruments are materializations of previously agreed-upon ways of structuring the world. The temperature scales used, for instance, are human constructions as is the language through which the computer functions. Thus, while nature certainly acts upon the computer, the reading the computer gets is coded by the society which built the computer. Second, the computer's activities are determined by the research program of Phillips' company and, in this case, of the larger society represented by EPA, which directed that low-pollution engines should be built. Thus even the depersonalized writing of the computer is socially shaped.

Phillips had a few computer-generated data sheets but not many because, as will become apparent, the information in the data sheets had usually been transformed into a more generalized form in another report. Phillips found these later forms more meaningful and more useful. One can distinguish here between a document's authority and its usefulness. Data sheets were the most authoritative evidence in that later documents could not contradict them once they had been accepted as accurate. But data sheets were also the least useful for Phillips in writing his paper because, despite their socially-constructed aspects, they contained the least interpretation, the least meaning. Interpretation and meaning were provided in later, supplemental documents.

The most common later documents were figures from oral presentations. Phillips had eight sets of handouts from presentations given by two people who worked for him. At one point, he called these handouts, not the engine, "the raw material" of his paper. In Phillips' company, most decisions about research are made in meetings at which engineers orally present their progress to management (cf. Paradis et al. 297). Phillips said progress was reported orally rather than in writing because meetings took less time than writing and gave an opportunity for group discussion, that is group interpretation, of the data—social construction of facts. As he said, "People can look at the data and make different comments than other people might. Or they'll say 'gee that's good but that's not so good.'"

The oral nature of these meetings, however, does not mean that they are free of writing. At the beginning of these meetings, speakers pass out handouts. Each page in the handout is a copy of a slide or transparency the engineer will show in his or her presentation. That slides or transparencies are on film rather than paper does not change their written nature. The handouts are simply a more conventional version of that writing, provided so that each participant can have a record of agreed-upon knowledge. Those present at the meeting use their handouts to make notes on, thus modifying the speaker's text to reflect and solidify the agreement reached orally at the meeting. Thus Phillips had made pencilled additions to the various sets of handouts. In one set, for instance, he bracketed two curves on one page and indicated that the difference between them was 20%, as those at the meeting analyzed how much progress they had made. On another page, he supplemented a graph showing what would happen to one pollutant under a given condition with numbers showing what would happen to a second pollutant not originally shown, as those at the meeting discussed how conditions that would help reduce the first pollutant might increase the second.

In addition to reflecting group interpretation, these handouts were more useful to Phillips than data sheets because of their graphic form. Usually the first sheet of the handout gives the title and perhaps an outline of the presentation, and then all the others are graphs of some sort. These graphs are sometimes hand-plotted from data sheets or more often plotted directly by the computer using the same data it uses to create data sheets. The graphs are thus a more generalized version of the data sheets. They are also more selective, since the speaker doesn't present all the data but only those which are, as Phillips said, "relevant." The graphs' generalized, selective nature thus makes them more interpretive than the data sheets. Charles Bazerman has noted the degree to which graphs are an interpretive form:

> Graphs, in addition to displaying data, show trends and allow comparison with other data and with theoretical predictions displayed on the same or neighboring graphs.

Thus, in contrast to tables, in graphs,

> the display of data [is] more purposeful, interpretive, intellectually complex, and intertwined with the theoretical argument of the paper. ("Modern Evolution" 180)

The interpretive nature of the graphs from the oral presentations was part of what made them useful to Phillips.

The importance of these handouts to Phillips' writing is shown in his listing as co-author the subordinate who made six of the sets of handouts and gave those six presentations. Phillips had decided on his own to write the conference paper and had prepared a draft before a co-worker suggested that Phillips' subordinate should be listed as co-author. Phillips agreed and added the subordinate's name to his own on the draft. The subordinate's name actually appeared on the draft for several weeks before anyone told him he was a co-author. His involvement in the putting of words on paper came before Phillips wrote the conference paper, but Phillips saw it as vital, as is shown by his response when I asked if his subordinate had done any of the writing:

> No. I gave him a copy after I finished drafting and he's supposed to be editing it. But, of course . . . when he finished the work on the naturally aspirated engine, he wrote an internal R&D memo which is normal, standard procedure. . . . And [the subordinate] had, of course, put on oral presentations throughout . . . so I had . . . oral presentations that he had done.

The subordinate made only a few minor changes in Phillips' draft. His "co-authorship" was thus based on the development work he had done, as inscribed in the documents Phillips was using.

The other documents Phillips used heavily were Progress Reports and Technical Reports, which are both written after a body of research has been completed and which document what has happened. Progress Reports are sent by research engineers to another of the company's divisions, which is responsible for getting the engine onto the market. This other division actually requests the research and pays for it. Technical Reports are progress reports which stay within the R&D area. They go to technical people who have been involved, their management, and the company library. Phillips had several Technical and Progress Reports, and he used them because they summarized and interpreted a large amount of activity. These reports reflected final, agreed-upon knowledge, and it was in them, not the engine, that the knowledge lay for Phillips.

Knowledge of Document Equals Knowledge of Thing

The result of all this is that for Phillips, knowledge of the engine and knowledge of documents about the engine were identical. This was evident in a conversation I had with him about how he wrote his own paper. His paper was on the engine's development and was intended to give information about engine behavior which researchers had picked up along the way rather than to describe the final engine configuration, which, as I have said, was readily available in the marketplace. He used the documents I have mentioned by ordering them chronologically, selecting a starting point, and then using the order created to provide content and structure for his paper. Using the documents, he said, he

> could start with the one I had decided was appropriate and say the first thing we did was test this . . . and then here are the results. Then I went through various things that we tried that were successful and unsuccessful.

When I asked him, Phillips said that by "going through various things," he meant going through various handouts. Thus a document describing a "thing" is substituted for the "thing" itself.

The blurring of the line between document and thing is also evident in the conference paper Phillips finally produced. The first page and a half of the eleven-page paper describe the physical configuration of the engine and contain five photographs of engine parts. These photographs and the accompanying sentences seem to refer directly to physical reality: "The engine uses a lightweight, linerless block with an open-face fire deck (Figure 1)." In the second half of the second page, however, the figures change from photos to graphs, and photos never return. Graphs are, of course, a written trace several steps further removed from thing than photos are. Sentences like the following begin to appear: "This modification of the fuel/cycle curve was accomplished by using a thin, rectangular feed port for the plunger for the 8.2L injector instead of the normal round hole." Note that this sentence talks about altering the "curve" on a graph (that is, writing) and altering the engine as if the two were equivalent. The next sentence continues this treatment of engine and writing: "Figure 6 shows that this unusual feed port increases the fuel/cycle at higher speeds (due to throttling of fuel escaping during the feed port closure) and the result is reduced fuel/cycle slope." Here, writing (that is, Figure 6, which is a line graph) is evidence for engine behavior (an increase in the amount of fuel per cycle) which in turn alters writing ("slope," a characteristic of graph lines). Writing about the engine and the engine itself are unclearly differentiated. For Phillips, at any rate, engineering knowledge was knowledge of documents at least as much as knowledge of things. This is not to say that he had no knowledge of the thing, only that he had no knowledge that was not inextricably bound up with writing.

Writing the Engineer

Engineers think of themselves as gathering facts and then acting. They usually view reports either as a means of presenting facts to management so that action can occur or as a way to store facts for future use. Examination of the documents Phillips used and produced, however, suggests that, in his case, they also have what Clifford Geertz refers to as an "interpretive" function for the engineers themselves. As Geertz says cockfighting is for the Balinese, for Phillips and his colleagues a report is often "a story they tell themselves about themselves" (448). Like the Balinese cockfight, such reports have a free element of art or ritual or play about them, supplementing their practical uses. In this case, the reports are designed to show the writers' respect for fact-based actions and thus show that they belong to the community of engineers.

This function of reports is demonstrated, for instance, in the form of what Phillips' company calls Technical Reports. These reports summarized a body of research which might have happened over periods as brief as a month or as long as two years. Phillips thought of them primarily as a resource for future researchers. They went to his company's library, where they were, he said, "the only permanent record we have of what happened." The reports' design, however, does not match this archival purpose. For one thing, Technical Reports always include a list of recommendations despite the fact that they are written after development work has ceased and decisions have already been made. Many of the recommendations made in a Technical Report have actually already been carried out. Thus, for example, one recommendation in a report Phillips was using reads "Re-evaluate and clarify tip spray angle effects," although tests to accomplish this were already being carried out before the report was written and distributed. According to Phillips, any recommendation which had not already been acted upon was not likely to be. So why include the recommendations at all? After pondering this question, Phillips said he did not know. Their inclusion was simply customary.

A similar pattern was observable in the Progress Reports sent to the company division requesting and budgeting for the research. These reports were written after work had been concluded and decisions made. Their recipient had already been given all the information contained in them in oral presentations used for decision making. The Progress Report's purpose, then, was to "go to [the division] in a kind of formal way and they would have it and it would show why we were doing what we were doing and what the result was." That the division already had this information was irrelevant. In other words, these documents justify decisions already made but are written as though they are the basis of the decision and would logically come before it, not after it.

This puzzling inclusion of recommendations and reasons for already-made decisions suggests a function for these documents beyond their practical one. These documents were not intended to fool anyone. Most of them would never actually be read by anyone. What, then, could be the function of the documents' supplementary elements? One possible explanation is that the primary object of such writing is to interpret these engineers' activities to match engineering ideals. Engineering decisions are often made in the middle of research where conclusions are not clear at all. They are necessarily based at least partly on hunches, creative instinct, and tacit knowledge gained from past experience. But these factors have no place in engineering ideals, which stress logic and relying on facts that will speak for themselves and make decisions obvious. These writers seem to be explaining their actions to one another and most importantly to themselves so that those actions would square with their ideal notion of themselves and their work. They were, in other words, writing themselves as engineers.

Logic as a Plausible Story

Scientists have previously been described as performing a similar kind of self-interpretation. In an article called "Is It Possible to Reconstruct the Research Process?" Bruno Latour discusses the published papers produced by a group of scientists working on protein synthesis. Of the scores of possible protein analogs, the scientists worked on only a few. The analogs to be worked on were not chosen totally randomly, but neither were they chosen as part of a totally logical research program. Analog choice, for instance, could come about because a scientist working elsewhere had published a paper which made trying one analog easier than trying another; or equipment could be available to make one choice more plausible than another. No matter how the choice was made, however, published papers presented the analogs in logical groups. Although the groups and therefore the logic used varied from paper to paper, groups of analogs were always presented as though only logic had determined their selection (64). Latour sees what we might call this "creative accounting" as a kind of logic. "If logic," he says,

> was taken out of the laudative meaning that it has [had] since Aristotle and was understood as logos or path, then we could say the [purpose of the] research process is to build paths, or, to use another source of metaphor, to tell plausible stories. (66)

Scientists create rather than describe a logical world in which they themselves behave logically.

In Phillips' account of writing his own paper, the creation of a logical, engineering self is evident. Phillips even used terms similar to Latour's. He repeatedly described himself as "telling the story" of the engine's development, and he knew he sometimes rearranged the facts for the sake of the "story." When he went through the handouts from the oral presentations, for instance, he had to decide what to include. "In some cases," he said,

> there are some anomalies in the data that are hard to explain and you have to think how am I going to explain them or how am I going to avoid showing them so that we don't have to explain them and so we have a nice, consistent story to present.

He included one finding that was, he said,

> a little bit misleading because the improvement we made to meet '88 [emission] standards we'll actually undo for 1991 standards because we've learned it's detrimental to 1991, but we won't tell people that.

He departed from his original list of items to be covered because, as he said, sometimes "you find out you don't have good information on that or the test was not accurate or quite confusing so you might say 'I'll skip that subject.'" His difficulty, Phillips said, was "trying to figure out how to make a sensible, clear story out of data . . . and yet [not] confuse by showing other results." For Phillips, as for the other writers who produced the Technical Reports and so on described above, telling a "sensible, clear story" was important not only because it would be easier for the reader to follow, but also because it would create the writer and the knowledge community he represented in a desirable way.

Because knowledge communities have a stake in how those representing them appear, communities both aid and limit individual members in creating desirable selves. They do so through the forms of writing available (cf. Miller, "Genre"). The standard formats available in any discipline control the way a writer can create his or her self. Thus, for Phillips, the inclusion of recommendations in a Technical Report is a matter of custom, and so he does it. He thus demonstrates his mastery of what Toulmin calls a discipline's "transmit," its forms of explanation:

> [T]he core of the transmit . . . is the repertory of intellectual techniques, procedures, skills and methods of representation, which are employed in "giving explanations" of events and phenomena within the scope of the science concerned. (159)

For an engineer to be accepted as an engineer, he or she must write and speak in the already-created forms and tongues of engineering. Thus, while it is possible to say that engineers create themselves in texts, it is also possible to say that they are created by the texts available to them.

Conclusion

This study is, of course, extremely limited in its scope, and further research needs to be done. Phillips is only one writer in only one company. There are, moreover, certain aspects of his work which may make him more dependent on writing than other engineers would be. First, he works in a Research and Development department and thus could be seen as functioning more like a scientist, more like a knowledge generator than, say, an engineer in one of the plants producing the engine he helped design. Second, his research is on engine emissions which are, for the most part, invisible to the naked eye and thus may depend more on translation to writing than other research areas. I suspect, however, that observations of engineers in the work place will reveal a large dependence on writing, particularly if they include observations of writing such as instrument traces, data sheets, and log books. Selzer, for instance, observed an engineer consulting numerous documents as an inventing technique. These pre-report documents are important parts of knowledge generation whose study has been largely neglected in favor of knowledge-transmitting reports.

In addition, despite the factors mentioned above, there are reasons to believe Phillips and his company are fairly typical in the way they work with writing. Phillips' communication skills were rated "Outstanding" in his most recent evaluation, and thus his writing cannot differ much from what his company desires. Moreover, the paper he produced was accepted by and presented at the national conference of the Society of Automotive Engineers, suggesting that his writing also fits the expectations of his discipline. In addition, engineers leave Phillips' company to work elsewhere and come from other companies to his. Phillips himself worked at another company for two years before joining his present employer. Though different companies do, of course, have different local practices, people seem to have little trouble adjusting, suggesting that the practices described here are common ones.

I used to tell my engineering students that writing is what engineers do. By this, I meant simply that they would spend more of their work time writing than they probably thought they would. This study suggests that writing is, indeed, what engineers do. They inscribe a written representation of physical reality and then use more writing to build agreed-upon knowledge and their own characters as engineers. In inhabiting a world of language, engineers are not unique. Indeed, as I said in the opening of this article, they resemble the rest of us, just as our theories would predict. The engineer differs from the rest of us, perhaps, only in showing greater resistance to knowing that language mediates experience. For those who choose to work with machines, belief in their direct presence is very important because direct presence can allow direct mastery of and power over reality. That the mastery comes through language raises the distressing thought that it may be "only" mastery of language.

Exertion of power through language is obviously not limited to engineers. As I worked on this paper, I was uncomfortably aware that I, too, was attempting to exert power. In particular, I am one of a group of researchers outside technology and science who claim that scientists have no special way of knowing unavailable to the rest of us. It seems to me that in part we are reacting to the privileged position our culture awards science and technology as ways of knowing. It is therefore likely that we exaggerate the irrational aspects of science. As a scholar of writing, it is great fun to say that engineers are actually writing about other writing, a field I presumably know more about than they do. They think their field, their way of knowing is superior? Nonsense! Their field isn't even their field; it is mine. But I also bow to privileged scientific ideology by posing as knowing empirically with nothing between me and what I see. Unmediated knowledge, however, is not possible for any of us. All writing, including mine, constructs the world which the writer can bear to inhabit.

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