APPLIED RESEARCH

SUMMARY
- Reports on the use of graphics by engineers as a method of stimulating the writing process
- Shows that graphics have a powerful function in stimulating writing ideas
- Describes patterns in graphics types based on the genre, and the most common types used

Graphics and Invention in Engineering Writing

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INTRODUCTION

An indication of how integrally graphic material is used in the production of engineering writing can be seen from a study of the use of graphics by 15 engineers as a method of stimulating the writing process. Each participant answered questions about a variety of genres, so that one participant might discuss, for instance, seven or eight genres of writing. From all 15 participants, 113 responses were recorded, and of that number, in only five cases did the respondent indicate that graphics were not used at any point when writing that genre.

Conversations with the engineers in this study seemed to show that it is natural for them to record information in graphic form and to use graphics during design work. As one participant said of his work habits, he will have a pad and pens available every day for sketching, particularly in the design phase. As a technological offshoot of this way of working, another engineer indicated that he will "rely heavily on the computer for data evaluation" to produce graphs, PowerPoint, Gantt charts, and sketches of both mechanical and electrical drawings.

These engineers also interact with one another using graphics. When asked whether graphics use was a normal part of daily activity, a third person said that drawing and sketching were sometimes more helpful, that this was a "very common interaction among engineers." When asked the same question, about whether he uses graphics to communicate, another respondent answered, "Sure do. All day." Because of the way they work, it seemed probable that when these engineers produce text, they would integrate both ways of symbolically representing information, text and graphics. As it turned out, every engineer in this study used graphics to stimulate ideas when writing.

More substantively, every person indicated using graphics as a source of ideas for writing in multiple writing genres, and for every person this use of graphics could occur both before composing (planning, thinking, making notes) and while composing (creating the text). Perhaps the clearest example was given by an engineer who described the creation of technical memos as a process that usually begins with math calculations, then includes graphs, often with pictures, and finally adds text. It is notable that as he describes this process, the writing comes last, almost as a kind of documentation of what has preceded it.

Engineers often operate as much by visual imaging as by linguistic description, if in fact visuals are not even predominant during design tasks. The feeling of engineers toward the use of graphics is epitomized by an engineer quoted by Kathryn Henderson: "Without the drawing, you know, it's just talk" (1998, 82). To fully function in the workplace, however, engineers have to use written language to interact with people who do not use the same visual imaging that they do. Thus a basic engineering method of symbolically representing ideas, visual imaging, must work with a completely different method, language and writing.

For those who are interested in engineering writing, the interaction between graphics and text is a possible area of research. Taking into account more than the finished text, looking at the process that creates the text, as I am doing here, expands the research concern. From that point of view, it becomes informative to look at how graphics are used by engineers during the writing process as a method of invention.

The rhetorical concept of invention has a long history. As Janice Lauer (2004) points out in *Invention in rhetoric and composition*, there has been (and is) a great deal of disagreement in rhetorical study about the function and use of invention. Drawing on Aristotle, I am defining invention

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as methods for discovering what to say when speaking or writing. Early methods of invention included lists of topics that might generate ideas, along with standard lists of questions (stasis questions). In the Middle Ages, writing manuals (on composing sermons, for instance) added to invention techniques, and still later came techniques involving genre format, such as the format of science research articles. As this article tries to show, visual graphic material can also serve an inventional function, at least for some kinds of writing.

In spite of the potential for research in this area, there are few studies that consider graphics as they are used in the writing of working engineers. One of the works that does address this topic is Henderson's book *Online and on paper: Visual representations, visual culture, and computer graphics in design engineering* (1998). Henderson looks at the uses of graphics by engineers and the importance of graphics for development of ideas. One engineer is even quoted as saying, "I can't think without my drawing board" (27). Although Henderson's book makes clear how integrally engineering thinking is bound up with graphics, Henderson does not focus directly on graphics as invention for writing.

Looking at graphics in engineering at a closer level of detail, Christina Haas and Stephen P. Witte (2001) have described the discussions held by working engineers during the process of revising both text and graphics. That study, which focused on how embodied knowledge gets represented, looked at the writing/revision process as it occurred, with some detail on how text and graphics affected one another. Reports such as this one by Haas and Witte are particularly good for letting us see the detail on how text and graphics can operate together.

To investigate the use of graphics in engineering writing, I talked with engineers at two different companies about their writing. In *Invention in rhetoric and composition*, Lauer writes that "The acts of invention often occur intensely in the early phases of writing but can continue throughout the composing process" (2004, 7). In this study I have paid attention to that process, concentrating on how these engineers used graphics before composing text as well as while composing.

I define graphics as any material that visually represents information on paper or on a computer screen, but that is not standard text. Graphics thus include not only photographs and charts, but also tables or computer printouts. This study concentrated on general writing practices among the engineers I talked to, rather than examining individual pieces of writing in detail. The purpose here was to gain a broader knowledge about how graphics serve an inventional function in engineering writing. Understanding this interaction has a definite importance for technical communicators who work with engineers, and this study attempts to increase that understanding.

PSYCHOLOGICAL EFFECTIVENESS OF GRAPHICS

My study makes it clear that engineers do use graphics for invention, but knowing that they do so cannot lead us to automatically assume that this is the most effective way for them to write. It could be possible, for instance, for engineers to use graphics simply out of habit and personal comfort with that method of representing information. The use of graphics for invention, however, may be based on more than mere familiarity.

The means by which graphics increase text comprehension have been studied, and researchers have suggested various ways that material may be mentally processed. One suggestion that is found repeatedly is the idea of a "mental model" of textual material, a model that may be a physical object but may also be a more abstract representation of ideas. The suggestion that graphics aid in creation of mental models is supported by Valérie Gyselinck (1996), Arthur M. Glenberg and William E. Langston (1992), Mary Hegarty and Marcel Adam Just (1989), F. Ganier and colleagues (2000), and Wolfgang Schnotz (1993).

Schnotz, for example, describes the advantage of graphics for mental models:

> *A text leads to the construction of a propositional representation which then allows to construct a corresponding mental model. A graphic, however, as an external analog representation provides the possibility of a relatively direct construction of a mental model . . . . (1993, 248)*

Schnotz proposes that graphics may aid in constructing mental models because text is stored only in verbal memory, whereas graphics are stored in both verbal and visual memory, providing an advantage not only in occupying more memory, but in creating a memory that already contains a kind of visual model. Ganier and colleagues also suggest that mental processing is quantitatively increased by use of graphics, as they say that text plus graphics provides two ways to access information and clarify ambiguities (2000).

These models of mental processing have implications for the use of graphics as a stimulus for invention in writing. If graphics do provide more accessible mental models, it may be that an increase in access to these models (which can be visual metaphors of ideas) can stimulate new ways of seeing those ideas, or of connections between ideas. A different reason why graphics may be an effective catalyst to invention may be found in *Sketches of thought*, by Vinod Goel (1995). Goel describes the design process by saying that the early stages of that process require an ability to "transform one symbol into another" and "transform one idea into another" (193), which allows the de-

signer to remain open to ideas and possibilities. According to Goel, "dense and ambiguous symbol systems" (194) are more likely to allow such transformation to happen. He contrasts free sketching, which he sees as dense and ambiguous, with drafting, which he believes is not. If Goel is correct, then some graphics, if not all, may operate in writing invention by increasing the likelihood of transforming one idea into another.

BACKGROUND TO THIS STUDY

The information in this article comes from an ethnographic study I conducted over the course of several months with engineers in private industry. Ethnography involves going out to observe another "culture," and in this case, I observed engineers rather than, say, Pacific islanders.

Michael Agar (1980) describes two general attitudes toward data collection in ethnographic work: (1) data can be based mostly on observation rather than what the study subjects say, or (2) data can be taken from conversations with those who inhabit that culture. I followed the second philosophy (which happens to be Agar's philosophy as well) and talked with participants from two companies located in southern New Jersey.

It is also the case that an ethnographic study is shaped by what is learned as the researcher goes on, and my experience bears out this observation. Five participants worked for a company that makes sophisticated communications equipment, often with the government as a client for their products. Because the products made by this company are used in such sensitive situations, every object made is subject to individual testing, with voluminous recording of results, and those written records also go to the client. As one engineer at the company put it, "You're selling paper and the hardware comes for free."

The other 10 participants in the study worked for a local branch of a multinational company that makes consumer products. The local branch used in this study employed about 750 people.

To use Agar's terminology, my respondents at both companies were "opportunistic"; that is, I talked with whomever I could. At the consumer goods company, however, many people were instructed to talk to me by a supervisor who became interested in my study. Of the 15 engineers who provided information for this study, there were 13 males and 2 females, and the experience level of the participants ranged from relatively new engineers (two years of experience) to those with several decades of experience (40 years).

I began the study with the intention of focusing on the use of graphics, an idea that arose from Dorothy Winsor's article "What counts as writing? An argument from engineers' practice" (1992). I began gathering information in a broad way—what Agar calls "informal interviews"—in which respondents can say anything they want, including critiquing the questions of the interviewer (1980, 90). When I began, though I knew that I wanted to investigate the use of graphics, I did not know that my final results would concentrate on graphics as a method of generating ideas for text.

In the end, this study consisted of several steps:

1. I began by asking questions of several engineers at both companies to get an idea of writing practices at each company. These interviews gave me information about both companies and some idea of the writing practices at each one.

2. Based on what I learned from the early conversations, I generated a formal set of questions asking for more detailed information on specific genres that had been suggested by participants. At this point I began to focus more closely on the interaction between text and graphics. This formal set of questions was posed to the same engineers I had talked to in the early conversations.

3. Information gained from the formal set of questions led to the creation of a final, longer questionnaire. It is common in ethnographic work to move gradually from an informal to a formal step, as in this case. This questionnaire focused on a range of possible graphics and on 13 writing genres that I had been told were used at either or both of the companies involved. For this questionnaire, the number of participants was expanded to include 15 people. The information from that final questionnaire provides the data for this study.

In the final interviews, I asked about 13 writing genres, all of them suggested by engineers at one or both of the two companies. I did not ask participants to try to define the suggested genres. Instead I used the language of my respondents and let them decide whether they engaged in writing that would match the genres on the list. Not all participants used every genre. The number who claimed to use a given genre (out of 15 total participants) is indicated here for each genre included in this study:

- Engineering notes (13)
- Test log (7)
- Design review (11)
- Status report (12)
- Test report (9)
- Failure report (3)
- Test procedure (10)
- Equipment procedure (5)
- Repair procedure (4)
- Proposal (9)
- E-mail (15)
- Paper memo (5)
- Paper letter (4)

TABLE 1: LIST OF GRAPHIC MATERIAL TYPES PRESENTED TO PARTICIPANTS WITH THE QUESTIONNAIRE

Numerical/Linguistic

1. Tables
2. Spreadsheets
3. Computer-generated data lists
4. Charts or graphs (line graphs, bar graphs, pie charts, flow charts)

Sketches and Drawings

5. Orthographic (two-dimensional), hand-drawn
6. Orthographic (two-dimensional), machine-drawn
7. Isometric (three-dimensional), hand-drawn
8. Isometric (three-dimensional), machine-drawn
9. Schematics (electrical, pneumatic, and so on)

Illustrations

10. Artistic illustrations (with unnecessary detail or color)
11. Photographs

During the interviews conducted using the final questionnaire, participants were also shown the list of types of graphics in Table 1, so that all answers referred to the same list. Answers about types of graphics were given and recorded by the numbers on this list.

As participants looked at the list in Table 1, I asked which types of graphics they might use with each writing genre to organize ideas prior to composing text, or to help generate ideas while composing the text. Examples of three types of graphics from the table are shown in Figure 1 (isometric drawing), Figure 2 (orthographic drawing), and Figure 3 (schematic).

HOW THESE ENGINEERS USED GRAPHICS

Looking in detail at how graphics affect writing, I noted immediately that the participants of this study had developed individual ways of working that were more important than general trends. Individual differences were thus likely to override broad patterns. I found no clear patterns at all based on years of experience, nor could I find clear differences between the two companies involved. The types of trends that I found are based on (1) overall number of graphics types used by each writer, (2) particular types of graphics used by each writer based on the writing genre, and (3) most common types of graphics overall.

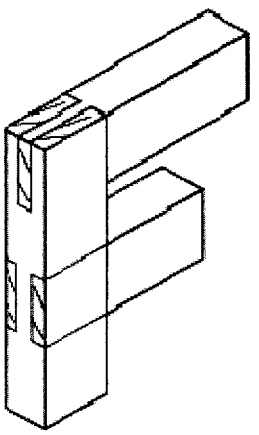

Figure 1. Isometric (3D) drawing. Used by permission from Geoff's Woodwork, http://www.geoffswoodwork.co.uk/ortho_drawings.htm.