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ABSTRACT

This paper synthesizes some of the many ideas and issues pertaining to research on the development of writing skills, and on creating new technologies for writing. Such technologies include computer-based production tools, videodiscs, and other mass storage technologies with potential for knowledge storing and structuring. The discussion also explores how these technologies help link the creative powers of the human mind, particularly in relation to the writing process, with the symbolic powers of the computer. Specific topics include: (1) goals for writing development; (2) historical background of computer writing tools; (3) cognitive science and writing development; (4) novice writers: children vs. adults; (5) future prospects of cognitive writing technologies; (6) local writer-related issues; and (7) the broader issues of society, schools, and family. The report also addresses the problems of software designers in generating writing tools that will be qualitatively better than those that are currently available, and concludes with an extensive bibliography. (JB)

CENTER FOR CHILDREN AND TECHNOLOGY

Toward Cognitive Technologies for Writing

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Technical Report No. 30

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Abstract

Writers of diverse skill levels are writing with computers, and many children have begun to write with a keyboard before touching pencil and paper. Clearly, the practice of writing in schools and everyday work settings is changing in fundamental ways. This paper is a synthesis of some of the many ideas and issues pertaining to research on the development of writing skills, and on creating new technologies for writing. The paper draws attention to the fundamental issues that both researchers and software designers must address if the next generation of writing tools is to be qualitatively better than what is available today.

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December 1984

TOWARD COGNITIVE TECHNOLOGIES FOR WRITING*

Roy D. Pea and D. Midian Kurland

> Ludwig Wittgenstein: It is only the attempt to write down your ideas that enables them to develop. (Drury, 1982)

We believe that radically different kinds of discourses will be necessary if the next generation of computer technologies for writing is to be more than marginally better than today's. It is not that we do not find useful the many available computer tools for writing, but rather that we do not feel that that is what is important. An exciting new perspective on writing tools is emerging, at the interface of theory and practice, from interactions between writing teachers, computer scientists, cognitive and developmental psychologists, and practitioners and students of literary creativity.

What we so desperately lack--in something beyond embryonic form--are cognitive technologies for writing that more closely connect the activities of thinking with those of writing. What we would like to do in this essay is trigger some thinking and dialogue on how writing technologies could go beyond functions of utility, to functions that can best be described as "cognitive." In talking about cognitive writing technologies, we refer to technologies that help a writer to develop the cognitive activities that are ingredient to writing processes. More on that shortly. But our immediate concern relates to the (perhaps too familiar) uncomfortable feeling one gets when asked, as

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a consumer of computer writing tools, whether there are any qualitative differences between writing with word processors and writing with noncomputer technologies. There certainly are some advantages, but they can be difficult to articulate and are not orders of magnitude greater than those afforded by the support of a secretary and his typewriter.

As a preliminary, we may note that, as we view it, cognitive writing technologies are not just "useful" for getting writing done faster or with fewer spelling or grammatical errors, but are tools that can directly serve to develop writing skills, be the writer adult or child.

Cognitive technologies that help develop writing skills involve effects of a different order of magnitude than the fine-tuning of meaning afforded by an on-line thesaurus, or contemporary software that catches a writer's lapses in noun-verb number agreement or computes text readability. For example, we could improve our argument structures in texts (Toulmin, 1958), make points more persuasively, serve up evidence more effectively in support of a case, better embody canons of rhetorical form and literary style, and better exploit the power of metaphor and analogy. We could take much greater advantage of our "inert ideas"--knowledge that a writer can express in speaking but does not use in writing (Bereiter & Scardamalia, 1984a). We could do much better at finding our own "voice" in writing that distinguishes our own text from someone else's.

In short, we suffer from an illusion if we believe that, even as adults, people cannot become profoundly better writers; any good writing course or apprenticeship will prove otherwise. And our children's difficulties in learning to write have become legendary. How wonderful it would be if our writing tools could work for us not only as slaves--merely implementers of our ideas--but as critics, support staff, research librarians, or colleagues. Could the universal symbolic powers of the computer eventually work with us collaboratively in such a deeply cognitive activity as writing? We think so, and if the reader will bear with us while we ruminate on the cognitive science of writing and indulge in flights of imagination, he or she may well agree.

To get a deeper sense of our direction, it behooves us to look into the distant past--several millenia ago--when writing systems first began to evolve (Diringer, 1962). There are many rich accounts of how the birth of writing systems and the spread of written language throughout the world radically changed the content and processes of thinking and education. Perhaps most significantly, this move from orality to literacy (see, especially, Goody, 1977; Ong, 1982) wrought fundamental changes in the objectification of language. The creation

of language as a permanent (written) rather than effervescent (spoken) physical form meant that it could be carefully analyzed and critiqued. Logic and mathematical systems grew from these new analytic possibilities. Texts also became distant from authors and more of the meaning had to lie within the text for it to be understood (e.g., Olson, 1977), since the author could no longer be queried face to face (Plato, 4th century, B.C.).

These newfound possibilities of written language had profound consequences for the powers of thought. Our weak information-processing capabilities became supported for the first time--in what we could describe as a cognitive revolution--by the externalization of thought as written language. As E.M. Forster aptly observed: "How can I tell what I think till I see what I say?" Hence, there is a venerable history of treating learning to write as closely connected to learning to think, both in history and in the individual (e.g., Bruner et al., 1966; Bruner & Olson, 1977-1978; Elbow 1983; Greenfield, 1972; Murray, 1980; Ong, 1982). However, these relationships are by no means guaranteed, but appear to depend on particular practices with literacy (Scribner & Cole, 1981). For example, Havelock (1963) has shown how the radical shift from an oral culture dependent on spoken mnemonic formulas for perpetuating accumulated knowledge freed the activities of the Greek mind for more original and more abstract thought. And the subsequent invention of the printing press and the widespread availability of books led to education of the masses, thus transforming the knowledge available to "everyman" (Eisenstein, 1979).

This truncated history leads us to our present consideration of how to link the creative powers of the human mind with the virtually limitless symbolic powers of the computer. Radically new cognitive writing environments can be invented, and their effective use could significantly transform not only the future development of thinking, but the processes and content of education.

Existing computer-based text-production tools, videodiscs, and other mass storage technologies have remarkable potential for knowledge storing and structuring. In addition, they have much greater potential than the vast storehouse of existing printed texts for allowing people to access stored knowledge on demand, and for allowing rapid, intelligent searches of text for specific content. The major question is how to configure these tools and harness them for cognitive writing technologies.

For instance, one can envisage making available to all writers the several million words in the English grapholect, with all their precision and expressive powers. Similarly, millions of images or symbols

in nonlinguistic media could be stored and accessed through an adjunct interactive videodisc to help spur the writer's memory and imagination for material to write about.

Let us consider the writing environment which consists of the activities of writing, the writer's longterm memory, and the "task environment." The interrelationships between task environment and writer memory are very intricate, since so much remembering consists of being reminded (e.g., Schank, 1982). We can imagine flexible systems that would allow writers of any skill level, while creating, evaluating, and revising text structures, to tap vast and highly accessible stores of knowledge that would radically extend memory and reminding--that would, in effect, break down the barriers between mind and machine and allow the ready flow of knowledge in the service of writing in an integrated human-computer writing system.

What would the access interface between these resources and the writer's creative processes need to be like? What kinds of questions could writers ask the system in order to find the path to the meanings they are seeking to express? How could the system help writers to realize and achieve the rhetorical goals they have for their texts? How would different skill levels in writing, and different knowledge of the language and its nuances, influence writers' search processes? Finally, how could an author's text construction and its organizational methods be linked to these materials in ways that guide rather than interfere with the writing process?

These imaginative leaps and challenging questions, however, move us ahead too far too fast. Little has been said about the writing technologies that are currently available, how writing skills develop in individual writers, or what the unique skills are that expert writers seem to possess. Since we will only be able to scratch the surface of each of these topics--so central to discussions about the development of computer-based writing technologies--we will cite relevant material for further exploration.

Goals for Writing Development

It is important that we first discuss the educational values and goals for developing such cognitive writing technologies. We echo Whitehead's question regarding any educational activity: How shall we prove its worth? From what has been said thus far, these tools appear to be important and promising, but toward whom will they be directed? And to what purposes?

We subscribe to a number of tenets about writing that inform our approach to cognitive writing technologies. These tenets do not hold

for all writing activities, such as keeping lists or ledgers, but they are central to many, from expository writing to penning novels, essays, or poetry: (1) to write is to think, to distance oneself and reflect; (2) writing can help solve the important problem of communication with others; (3) writing may make one a better reader; and (4) writing can give writers a better sense of their own voice, and thus serve in identity formation.

It is not our contention, in laying out these four points, that everyone should work to become an expert writer, any more than that everyone should strive to become an expert music composer. What we are suggesting is that most people could benefit from learning how to write better.

We find it useful to draw a rough distinction between writing as art and writing as communication. While most writing as art is also communicative, not all communicative writing is artful. This distinction is critical for thinking about the goals of writing development and the tools that serve the development of writing skills, because not all people have the interest in or knack for writing as art. And little of the functional, communicative writing people do in business and everyday affairs is or needs to be evaluated by aesthetic standards. Unfortunately, few people today are good at writing in either sense.

Yet writing as communication--that is, to persuade, inform, instruct--is a necessary basic skill in our society. For example, many people feel frustrated by their inability to write persuasive documents. And many people find it difficult to find structure in and remember the gist of texts when reading--a skill that could be aided by writing experience.

The problem is that both forms of writing are avoided. It is clear that, even if they wanted to become good at writing, few people would know what to do or where to begin. The craft of writing is surrounded by mythology, and today's computer-based writing tools leave the myths intact; they are opaque to the writing process. Virtually all of the current computer writing tools are designed for those who are already skilled writers; they are tools for <u>being</u> writers, rather than <u>becoming</u> writers. Good cognitive writing technologies should provide avenues for people to become better writers regardless of writing experience. Once chosen, they should provide <u>developmental writing environments</u>.

In sum, we believe that, with hard work, most people can become good, clear writers-as-communicators, capable of getting their point across to their readers. New cognitive writing environments could

provide genetic paths for them to make this choice and see it through. Before considering these possibilities, we must take stock of the development of computer writing tools in order to establish our current context.

Historical Background of Computer Writing Tools

Writing, by definition, relies on some pairing of trace-forming and recording technologies--stylus and clay tablet, quill and papyrus, chalk and slateboard, pen and paper, keyboard and screen/disk/printer. While "human word-processors" (i.e., scribes and secretaries) have always been available to a limited number of writers, major changes in writing technologies in the last few years have afforded text-editing capabilities to a much greater number of writers. More importantly, these capabilities have been made available to young writers at early stages of their development. We now find word processors in the kindergarten!

The move toward computer-based writing tools and computer-based writing instruction has proceeded through five identifiable phases. The first phase, which predated computers, defined the basic themes for much of what we find today. Starting in the latter part of the nineteenth century, the typewriter became sufficiently reliable to be considered a viable writing tool, not just a production device--like the printing press--for producing neat-looking copy. The first important use of typewriters to help teach writing occurred in the 1920s. For the first time, students as young as kindergartners were able to write at a keyboard and observe the results of their efforts on neatly typed paper.

In what no doubt remains the largest study of the effects of word processing on the writing of young children, Wood and Freeman (1932) studied 2,383 students over two years in hundreds of classrooms as they learned to write on portable manual typewriters. Wood and Freeman observed that, when compared with a control group who did their writing without benefit of typewriters, the students in the experimental classrooms wrote more and with more expression, showed gains in their reading scores, became better spellers, and expressed a greater interest in and enjoyment of writing. Despite these strong positive results and the wide acceptance of the typewriter as the basic tool of the professional writer, the use of typewriters in elementary school classrooms never really caught on. Nonetheless, this study and subsequent research by Wood and his colleagues provided the first inkling that superior keyboard-based writing technologies could have an impact on how novice writers learned to write.

The second phase in the move towards computer-based writing environments was the realization in the 1950s and 1960s that, in addition to manipulating the numbers it was originally designed to handle, the computer could be used to create texts. General-purpose program editors running on large mainframe computers were discovered to be suitable for entering text, as well as data or lines of programming code. Although clumsy by today's standards, these early editors and their descendants (e.g., ED, TECO, EMACS, ICE) demonstrated that it was possible to quickly merge and modify texts using basic editing commands. When these editors were coupled with formatting and printing programs, a viable writing system was created that had important advantages over the typewriter. In particular, it was easier to alter a document in a number of ways without having to reenter the parts of the document that were to remain intact. Thus, multiple revisions and multiple copies could be produced in a fraction of the time it had taken previously, even with the assistance of an efficient typing pool. However, these mainframe systems were expensive to operate, difficult to learn, and restricted to a small number of writers with technical backgrounds in universities and large businesses.

The third phase began with the development of less expensive minicomputers in the early 1970s. The development of the microprocessor later in that decade made possible the creation of personal computers, and allowed word processing capabilities to migrate from large mainframe computers down to smaller, more affordable machines. At the same time, integrated word-processing programs designed specifically for text production, formatting, and printing were developed to replace the older, general-purpose systems running on the mainframes. Thus, it became possible on a small personal computer to create a complete desktop writing and printing environment. There are now literally hundreds of word-processing programs available to run on practically all existing computers (e.g., the popular Wordstar, Bank Street Writer, Easywriter, Scripsit, Visiword, and Applewriter programs). In addition, there are computers with special keyboards and integrated high-quality printers that are dedicated to text production (e.g., IBM Displaywriter, Wangwriter).

Complete word-processing systems (computer, keyboard, mass storage device, display monitor, printer, and word-processing software) can now be assembled for less than a thousand dollars, although most acceptable systems still cost several times that amount. Such systems typically permit the writer to enter text as if at a typewriter. But they also allow the writer to quickly delete or copy letters, words, or phrases anywhere in the text; move blocks of text around; insert new text anywhere in the document without having to retype or rearrange the surrounding text; find and replace specific words or phrases;

change headings, margins, fonts, and line spacing at any time; have page numbers and running headers or footers automatically inserted; and part or all of the document printed out as many times and in as many ways as the writer desires.

In the past two years, as word-processing software has become less and less expensive, the number of computers in schools and homes has grown astronomically. As a consequence of these developments, many students are now doing some or all of their writing with word processors, and the use of the new portable computers by businessmen for writing while traveling has become widespread. As yet, writing instructors have not fully realized the instructional possibilities of students' writing with word processors (e.g., on-line conferencing and revising sessions with the student), but we anticipate that this will begin to happen more broadly once the novelty of the computer has worn off.

The fourth phase in the evolution of more powerful writing environments--riding closely on the heels of the third--has been the development of programs that work with a word processor to produce a polished text. Word processors permit the writer to insert, delete, and rearrange words at will, but do little in assisting the writer to plan or evaluate a text. Consequently, programs that provide some of these other functions have been developed.

The Writer's Workbench™ (Frase, 1983; Macdonald, 1983), a set of related programs developed at Bell Laboratories to augment text processing on the company's UNIX™ system, was one of the first and most complete support systems for writers. The Writer's Workbench and the many programs for microcomputers derived from it (e.g., The Word, Grammatik) take a text that has been produced with a word processor and evaluate it according to a set of algorithms designed to identify potential problems. For example, these programs check a document for misspellings and, on request, can suggest possible correct spellings for any word the program does not find in its dictionary. Other programs can check a document for unbalanced quotation marks or parentheses, incorrectly placed or missing capital letters, excessively long sentences, sexist language or jargon, overuse of the passive voice, and many other grammatical solecisms and stylistic infelicities. They can also provide statistics on such features as average sentence length, average number of syllables per word, number of technical words, and readability level according to various scoring methods. With this kind of information, the programs can reference stored exemplars of different types of text, compare the writer's text to these norms, and provide feedback to the writer about how closely his or her text conforms to established norms for a particular kind of writing. Thus, a writer could find out that the

sentences in her essay were on average seven words longer than the standard for a good essay, and that she used 23% more four-syllable words than the norm, which might make the text hard to read.

In addition to programs that provide feedback after a text has been produced (although the checked text can still be revised and reevaluated), there are programs that work in tandem with the word processor on-line while the writer is writing. For example, there are electronic thesauruses (e.g., The Random House Electronic Thesaurus) that permit the writer, in the midst of composing, to call up on the screen a thesaurus entry for any word, and have one of the alternate words in the entry inserted automatically into the text.

A third class of support programs that have emerged assist such prewriting activities as idea production, idea organization, and planning (Bruce et al., 1983). It is possible, but somewhat awkward, to use word processors effectively for creating outlines, for rapidly jotting down ideas as they spring to mind (i.e., "freewriting," or "flaming," to borrow John Seely Brown's term), or for organizing these ideas before beginning to shape the final text. But we now have specialized programs that provide extra structure and support for these writing processes. Some of the better known are outlining programs (e.g., Thinktank, Framework) and idea prompters (e.g., Planner). For the young student, there are programs that provide ready-made content, but allow the writer to experiment with alternative structures or organizations (e.g., Storymaker). While some of these programs are geared to the young writer, many of them in principle have potential application for writers at all stages of development.

These four phases have gone a long way toward improving the technical capabilities of the writing environment. However, even the most sophisticated of these computer-based tools still represent what are essentially slave technologies. Available writing tools have, for the most part, taken the place of typing support and, in some cases, the copy editor, but they cannot serve as constructive critic, writing process expert, responsive audience, or collaborator. Hence, the next phase in the evolution of writing technologies must begin to address these fundamental problems.

At the present time, major computer-based writing technologies under development, or in the planning stages, are proceeding along two complementary courses: to make the feedback available to writers more "intelligent," and to make more flexible, "personalizable" writing tools.

On the one hand, developers are incorporating recent advances in artificial intelligence and natural-language understanding to make writing programs that can provide more detailed and content-specific forms of feedback. IBM's Epistle system (Heidhorn, Jensen, Miller, Byrd, & Chodorow, 1982), now in prototype form and undergoing further development, combines a word processor with a powerful natural-language parser and an extensive dictionary and database of information about business correspondence and other document types. Together these programs produce a system that can evaluate any text by providing a detailed critique concerning, among other problems, subject-verb disagreement, wrong pronoun case, noun-modifier disagreement, nonstandard verb forms, and whether the distance between subject and verb is too great. In addition, this system will be able to take a prepared text and produce a synopsis of its contents, highlight important sections, and generate index terms based on conceptual or thematic characteristics. Critiques are also possible of the rhetorical structure of the text, given a definition of its document type (Lance Miller, personal communication, March 1984).

While the emergence of more intelligent systems like Epistle is imminent, writing technology is moving in a second direction. Writing systems are planned that can be flexibly modified by the individual writer, and eventually modify themselves automatically to complement the particular writing style or preferences of the writer (Brown, 1982).

Until now, even the most sophisticated word processors have been fairly inflexible. The order and manner in which they carried out their operations was set by the designer. These characteristics could not be altered by the writer and, in many cases, the writer was forced to adopt a particular writing style or method of text construction dictated by the way the program worked, not by his or her preferred working style. For example, some systems temporarily remove the surrounding text from the screen when the writer inserts a new word or phrase. Thus, the writer must decide what to say while the text is on the screen, give the insert command, and type the insertion without being able to refer back to the surrounding context until after the insertion has been completed.

Systems with greater flexibility offer some user control by permitting the writer to program function keys or create "macro" (e.g., ProKey) commands to perform a favored sequence of commands with a single keystroke or command. However, while such capabilities speed up editing and formatting within the existing system architecture, they have not allowed the writer to create a personalized writing environment of his or her own choosing. What is needed are "developmental" word processors that come with a simple set of commands and func-

tions that can, over time, be modified, extended, deleted, or redesigned to better support the individual writer as he or she matures. Such systems are also needed to better support the cognitive demands created as a writer switches from one writing genre to another (e.g., from technical writing such as a report or business letter, to expressive writing such as a short story or personal letter).

Writing technology has changed rapidly and in many directions during the past two decades, perhaps more than in the previous 200 years. However, the writing technologies developed thus far, no matter how superficially powerful, do not teach writing or help to make a person a better writer. To understand how technology interacts with the processes of writing, we must consider what the novice or expert writer actually does with the available writing technologies. Only then will we be in a position to suitably reflect on the form that cognitive writing technologies should take in the future.

Cognitive Science and Writing Development

Now we must get to the heart of what a cognitive science of writing is all about. Our key argument will be that, to date, research on the cognitive processes of writing indicates the accessibility of cognitive writing technologies. They are accessible because cognitive process models and writing studies suggest many "developmental fronts" where new tools could support the mental activities involved in composing text.

For years, many people have thought of writing as a mysterious process that only those "good at writing" could do. The widely publicized quirks and idiosyncracies, even superstitious habits, of many luminary writers have only added to this mystique: "One thinks of Schiller's rotten apples, Proust's cork-lined room, and Balzac's monkish apparel" (Green & Wason, 1982, p. 50; also see the Paris Review series on Writers at Work, e.g., Plimpton, 1981).

In recent years, we have seen a progressive demystification of writing, published largely in technical reports, whose findings have yet to make their way into public awareness. This important demystification process has been in large part due to extensive, careful investigations of the writing processes of novice and expert adult writers and the development of writing abilities in children, but also to rich observational accounts of the successful teaching of writing (e.g., Elbow, 1981; Graves, 1975, 1983).

How has writing become less mysterious? Although much mystery remains, there has been a major shift from viewing writing as an unanalyzed holistic process, to the widespread recognition that writing is a complex skill comprised of such distinguishable component activities as planning, translating, reviewing, and monitoring. Recent writing studies have paid special attention to the different cognitive activities involved in writing, seeking to identify its basic component processes, and how these processes are orchestrated or managed during the activities of writing (e.g., Bracewell, Frederiksen, & Frederiksen, 1982; Flower & Hayes, 1980a, b, 1981; Hayes & Flower, 1980a,b). And there has been a productive focus on issues of regulation and control of the subactivities of writing. Writing has been demystified to the extent that such accounts allow for systematic testing of alternative theories of how text is composed, and how writing skills are developed through instruction and writing practices.

The promise of improving writing instruction through various intervention strategies based on these findings has also been assessed, particularly in research programs at the Ontario Institute for Studies in Education (e.g., Bereiter & Scardamalia, 1984a,b; Scardamalia & Bereiter, 1983a,b). Since there are many excellent introductions to this work available (e.g., Beaugrande, 1984; Scardamalia & Bereiter, 1984), our main purpose will be to survey the prominent aspects that are central to the development of future cognitive writing technologies, and to provide a vocabulary that the reader can use in thinking about the cognitive processes of writing.

These cognitive studies of writing begin with the observation that writing is a complex cognitive task, one prone to obscurity because of the many cognitive demands that impinge on the writer all at once. Writing is viewed as "a process of generating and editing text within a variety of constraints" such as structure, content, and goals (Collins & Gentner, 1980, p. 52). On the one hand (perhaps the left?), the writer has ideas to communicate and experiences to embody in written text. The nonlinearity, rich imagery, and symbols of thought so glorified during the literary period of romanticism provide crucial but unrefined gist for the writer's tasks. On the other hand (perhaps the right?), the writer is creating a text structure governed by many constraints and conventions. As Alexander Pushkin so aptly put it:

> There are two kinds of obscurity; one arises from a lack of feelings and thoughts, which have been replaced by words; the other from an abundance of feelings and thoughts, and the inadequacy of words to express them.

Perhaps the most obvious conventions, and certainly the central emphasis of traditional writing instruction and current computer-assisted instructional writing programs, are those of spelling, word meaning, and grammar (Rubin, 1983). But larger units of analysis--closer to the ancient discipline of "rhetoric" pioneered by Aristotle (Cooper, 1932), reawakened and developed by Burke (1950), and today designated as "pragmatics"--also impose constraints on the writing process.

One must, for example, think about the objectives of the written piece, the anticipated audience, whether the topics and comments add to current knowledge or are already in the public domain, the structure of arguments, and the genre of the composition as a whole (e.g., essay, sonnet, mystery, letter). The author may focus on making the text enticing, comprehensible, memorable, or persuasive, and these pervasive goals of writing are realized through different structures and devices at different levels of the text (Collins & Gentner, 1980). Taken separately, each of these constraints may be manageable, but taken together they can constitute a serious impediment to human memory and cognitive processing. Like the centipede watching its own feet, a writer paying attention to all these directions may never set pen to paper (Flower & Hayes, 1980b).

The central concept of the above-mentioned cognitive studies is that writing is a problem-solving activity (Bracewell, 1980; Hayes & Flower, 1980b) comprised of a small set of basic mental processes. We believe that writing is a complex problem-solving activity, requiring the management of available mental resources to deal with the Janus faces of writing--the creative and the constraining.

This view of writing owes much to the general theory of problem solving developed by Newell and Simon (1972; also see Simon, 1981) and their colleagues. Since the 1960s, this perspective has been applied with great success to thinking and developmental processes in content areas from mathematics and science to chess and engineering, and has recently had considerable influence on instructional psychology (e.g., Gagne & Dick, 1983; Glaser, 1982; Resnick, 1981).

A major difference between recent work on writing development and earlier cognitive science accounts of problem solving for other content areas is the broader sense given to the term "problem solving." Whereas earlier studies emphasized the solving of problems with well-defined goals, it is now recognized that goals can themselves be altered during work on a problem. Problem finding has thus come to be incorporated into the study of problem solving; writers can redefine the rhetorical problem their writing is "solving" by means of the writing activity itself.

The cognitive science perspective will help us to fix a vocabulary for talking about writing development and roles for cognitive writing technologies. We will describe a cognitive process model of writing as problem solving, how data on writing activities relate to it, and the details of the model. In the remainder of the essay, we will explore how cognitive process models relate to the development of writing skills and, finally, cognitive writing technologies.

Although different investigators offer different cognitive models of writing, Flower & Hayes (1981) present a lucid account of their cognitive process model of writing, briefly summarized here, that suits our purposes (see Figure 1 for the structure of their writing model.) Three major elements of the task of writing are distinguished: the task environment (including "everything outside the writer's skin": what the rhetorical problem is, the text as it evolves, writing tools, and sources of information to be used in writing); the writer's long-term memory (including knowledge of topic, audience, and writing strategies); and writing processes (including planning, translating, and reviewing--controlled by an executive monitor). The purpose of such a model is to help sharpen thinking about writing by describing the parts of the cognitive writing system and how they work together to create a written text.

A process model centers for analysis on units called basic mental "processes," such as generating ideas. We can call any execution of a basic mental process a mental "act." According to this model, any of the mental acts described may be carried out at any time during the writing activity, and one basic mental process "monitors" the use of the others. These basic mental processes may be invoked advantageously and optionally at any point in the writing process.

A rich source of data for cognitive studies of writing are think-aloud protocols (Bereiter & Scardamalia, 1984b; Hayes & Flower, 1980a)--transcribed records of a writer's spontaneous descriptions of what is going on in his or her mind while writing. Protocols provide rich insights into what kinds of mental processes underlie the activities of text composition, and how they are juggled during writing. The kinds of mental acts different writers engage in while writing have a great deal in common, and the model attempts to capture these acts. However, the ways in which novices versus experts, or children versus adults, in fact orchestrate these mental acts during writing varies tremendously. Major findings from such studies will be cited below.

Before stating the basic mental processes that make up this cognitive model of writing, we must describe two elements of the writing environment depicted in Figure 1.

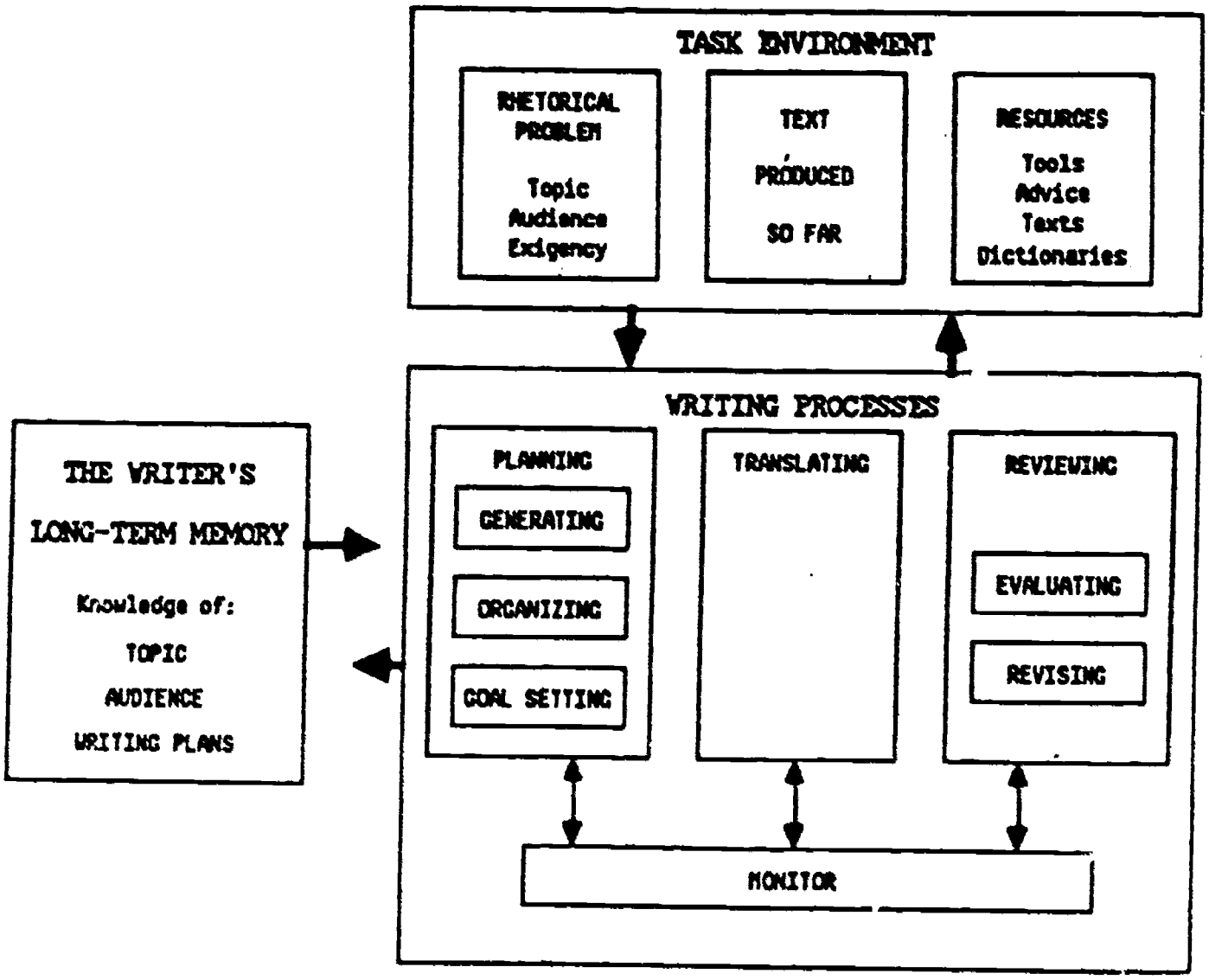

Figure 1. Cognitive processes of the writing model (adapted from Flower & Hayes, 1981)

As Flower and Hayes note, "the arrows indicate that *information* flows from one box or process to another; that is, knowledge about the writing assignment or knowledge from memory can be transferred or used in the planning process, and information from planning can flow back the other way....The multiple arrows...are unfortunately only weak indications of the complex and active organization of thinking processes" (pp. 386-387).

First, within the task environment:

1. There is a RHETORICAL PROBLEM to solve, such as: "Write a critical review of Bill's cheese omelette for potential future diners." Writing is the task of solving that problem, given some definition of topic and audience.

2. There is an EVOLVING TEXT, which opens or closes off options for how it can proceed according to the vast array of linguistic and rhetorical conventions already mentioned. For example, a topic sentence serves to limit and refine a paragraph's possibilities.

3. There are RESOURCES and TOOLS for writing, such as: teachers; books, index cards, and other reference materials; writing materials; and computer-based writing tools. We have added this box to Figure 1 in order to acknowledge the important role of such prior externalizations or thought for the creation of new writing. Resources have a critical place in the historical and technological context of writing development.

Second, within the writer's long-term memory (LTM), there is knowledge about topic, audience, writing plans, and types of writing problems. Unlike the active processing of short-term memory, LTM has a more stable organization, and the two major problems for the writer are to access the knowledge that will be useful for the writing under way, and to organize that knowledge to meet the needs of the rhetorical problem.

Now we move to brief descriptions of the basic mental processes of the cognitive process model of writing. Within the box called "writing processes," three major mental processes are shown: (1) PLANNING, (2) TRANSLATING, and (3) REVIEWING. A fourth, MONITORING, functions strategically to determine in what order processes are engaged in.

1. PLANNING is defined broadly as the act of building a representation (e.g., images, propositions, feelings) of the knowledge to be used in writing, and involves three major subprocesses: (a) GENERATING IDEAS, which includes accessing knowledge from long-term memory or resources that may not appear in the final text; (b) ORGANIZING, which helps to give meaningful structure to the ideas, and from which new ideas can emerge as a result of this browsing and combinatorial activity; and (c) GOAL-SETTING, which sharpens the definition of the rhetorical problem by generating and revising goals and subgoals for the text.

2. TRANSLATING is defined as the process of turning ideas into written language, and is subject to such constraints on linguistic form as spelling, syntax, and word choice, and to such pragmatic constraints as topical organization or the temporal sequence of narration.

3. REVIEWING is the process of going back over the text or such writing processes as planning, and involves two major subprocesses: (a) EVALUATING, by which outcomes of writing processes (such as translating or planning) are judged against certain standards; and (b) REVISING, by which changes are made in the products of the mental processes of writing (e.g., text, goals, or ideas). On the importance of revision, D. W. Harding reminds us that "the important thing is not what the author, or any artist, had in mind to begin with but at what point he decided to stop" (Gross, 1983).

4. MONITORING is the complex "executive" process that oversees writing processes and allows the writer to decide when to move from one mental process to the next (e.g., when to stop translating and start reviewing).

Several important empirical findings come from using this model as a tool for observing the progress of writing activities: (1) writing processes are hierarchically organized; (2) the guidance of writing processes emerges from goal-directedness; and (3) the goals of writing are epistemically reactive; that is, they are continually regenerated through what is learned during the writing process.

1. These basic processes of writing are not executed in rigid sequence, but are hierarchically organized so that they may be flexibly embedded within other basic writing processes. This observation counters "stage models" of writing that view text composing as a linear process of distinct stages, such as Pre-Write, Write, and Re-write (Rohman, 1965). Flower and Hayes (1981) cite an example of a writer who, after attempting to TRANSLATE the first sentence of a paper, created a subgoal sequence of PLANNING, TRANSLATING, and REVIEWING to try out another first sentence as part of the larger attempt to TRANSLATE. These modular processes may be selected during writing processes as "tools" to help solve the writing problem. Similarly, writing technologies that permit the writer to easily generate and compare alternatively worded sentences or paragraphs side by side on the screen or on a printout might help writers to exploit this aspect of the writing process.

2. Goal-directedness is what guides a writer to invoke specific mental processes during the act of composing, thus giving writing its purposefulness. A hierarchical network of goals is created (in fact,

often discovered as ideas are generated, organized, and translated into text), which directs the sequencing of mental processes. Evolving goals thus lay out the path for the composing process.

3. Not only does writing help promote thinking, but as we learn during writing, our writing goals often change. This finding is linked to our earlier discussion of the history of written language and its relationship to the development of such abstract systems as logic, mathematics, and science. While many goals for writing (e.g., "keeping the reader involved") may be automatically accessed from memory, the creative setting of subgoals and the subsequent discovery or redefinition of writing goals during the composing process is a basic fact about writing.

Writing Development

Thus far, we have said little about the question of writing development. Given the above cognitive process model for writing, what is it that develops, and through what transformational processes does this development occur? Do we know how to design an instructional psychology of writing? How could the cognitive writing technologies we are calling for support these developmental processes? These are big questions, and most research has only begun to address them. Our strategy will be to highlight findings on writing development that have significant implications for the kinds of cognitive writing tools that will be needed to foster writing development.

Our principal method will be to illustrate the main weaknesses or "stress points" in the cognitive system for writing in underdeveloped writers. Wherein lie their particular difficulties? We will cite findings from two quarters: comparative studies of novice versus expert writers (mainly adults), and comparative studies of child writers of different ages. Findings which demonstrate that the differences between good writers and novice writers lie in the mental processes they orchestrate and how they orchestrate them are of particular interest, and give rise to two important questions concerning new writing technologies: How can the knowledge that experts appear to have be made available to novices? How can cognitive writing tools serve us in this pedagogical enterprise?

Some clarification of the terms "novice" and "expert" writers is essential to our exposition. The most important proviso is that the term "novice writer," as used in the literature on the developmental psychology of writing, does not refer to nonwriting individuals, be they illiterate or functionally illiterate (i.e., those who rarely or never use what little writing skills they may have). Novice writers are individuals who do write--whether in school, for business purposes, or for

other functional activities in their lives--but whose writing is problematical for a variety of reasons.

The meaning of the term "expert writer" is more elusive in the writing development literature and does not necessarily refer to professional writers, such as novelists or journalists, although such people are often expert. But the popular definition of expert writers (i.e., those who write for a living) excludes a large group, such as academicians or business people, who write all the time. In both settings, writers are beset with many of the writing problems identified for precollege students, including children. Perhaps the best working definition is that expert writers are those who are recognized as such by their peers in the genre they have mastered.

Perhaps the chief distinction between novice and expert writers is that the novice reaches the plateau of writer-based prose and may remain there, never progressing to the reader-based prose of the expert (Flower, 1979). In this sense, many people remain writing novices forever. In writer-based prose, which gets most writers through their school assignments and many through business-related writing, the focus is on the text in isolation rather than on the text in relation to its intended audience. In Flower's (1979) words: "In its language and structure, Reader-Based prose reflects the purpose of the writer's thought; Writer-Based prose tends to reflect its process" (p. 20).

What Flower describes as writer-based prose would appear to be, in part, a literal translation of oral speech conventions into written language (Shaughnessy, 1977). Many of the other problems revealed by novice writers emerge as symptoms of this memory-dump approach to writing; for example:

- The central problem of managing the array of ideas generated from LTM and translated into text. Texts and text-production processes reveal little preplanning. There is no evidence of organization of ideas.

- The central problem of managing the array of goals writers may have for their texts, and inadequate efforts to set explicit goals.

- The central problem in revising text of finding the parts and organization of text structure. The novice writer's set of representations of the text is often limited to the text itself· the novice cannot state the main point or explain the rhetorical goals for the text, and sentences are arranged by topic rather than by their imagined effect on a reader. Bracewell et al. (1982) attribute these problems, in part, to the absence of a "concep-

tual frame" for the text--story (with its canonical forms) versus an associative event sequence (composed of "and then..." structures).

- The key problem of monitoring and managing the deployment of the different mental processes involved in writing: PLANNING (GENERATING, ORGANIZING, GOAL SETTING), TRANSLATING, and REVIEWING (EVALUATING, REVISING).

- The central problem of becoming aware of one's writing problems, and getting access to techniques and methods for overcoming and managing them.

Finally, a related problem for novice writers is that of recognizing writing as a multistage process. Hypothetically, their writing should improve with the realization that the more revisions a document undergoes, the better the final text is likely to be (assuming the revisions are done according to specific critical standards). Wason (1983) cites an exemplary writing process account from John Henry Newman:

> My book on Justification...I write, I write again: I write a third time in the course of six months. Then I take the third: I literally fill the paper with corrections so that another person could not read it. I then write it out fair for the printer. I put it by. I take it up again: it will not do. Alterations multiply, pages are rewritten, little lines creep in and sneak about. The whole piece is disfigured: I write again: I cannot count how many times this process is repeated.

Novice writers must also recognize the complex of cognitive processes involved in writing, so that their sources of difficulty can be identified and addressed.

There are central lessons here for the designers of cognitive writing technologies. Novice writers' diverse problems imply that since writing skills develop, putting the writing tools of the expert into the hands of the novice is not in itself likely to improve the latter's writing. Rather, entry-level tools are needed to bring children and adult novices to a skill level where they can maximally benefit from the expert's cognitive writing technologies.

Correlatively, the expert writer is likely to be hindered by tools designed for the novice's special needs. For example, the explicit prompting provided by word processing programs, such as those developed by Dauite (1983), may be useful devices for encouraging novices to consider whether or not their texts adequately satisfy their

stated goals. However, such explicit prompting would be irritating to the experienced writer and detract from the writing process.

Novice Writers: Children Versus Adults

Although research indicates a commonality of difficulties experienced by novice child and adult writers--particularly in relation to writer-based prose--there may also be differences. Maturational and experiential histories, for example, are quite distinctive for the two groups. And if child novice writers have an additional set of problems to overcome in developing writing skills, this has important implications for the design of developmental writing technologies. We will describe below some probable ways in which child novice writers are likely to diverge from adult novices or poor writers. Where these speculations (guided by a general knowledge of developmental psychology) receive empirical support from cognitive studies of writing, relevant studies will be cited.

1. Rhetorical problem and genre knowledge. Adults are apt to have read a broader range and more examples of text genres. This is likely to provide them with a more extensive knowledge base, and to give them greater access to ideas when writing to the specifications of a rhetorical problem in a given genre.

2. Topic knowledge and word knowledge. Knowledge access poses a greater problem for children since, in general, adults have a more extensive base of world knowledge. The same is true of word knowledge (Miller & Johnson-Laird, 1976). On-line dictionaries, databases, encyclopedias, and thesauruses may alleviate but not erase these differences. Having access is important but so is knowing what is appropriate in a given context, and this latter kind of knowledge cannot be "looked up" in any automated system we can envision.

3. LTM access. Because children (especially at the preoperational stage) and adults have differently organized long-term memory (LTM), their knowledge access strategies are also likely to differ.

4. Audience imagination. The development of social cognition is apt to have important effects on the child's ability to imagine audience, belief states about audience characteristics, and imagined purposes of the reader (e.g., reading for gist, for humor, for instructions).

5. Monitor. Insofar as discussing the monitoring of cognitive processes involved in writing is central to effective writing instruction (see Figure 1), there are likely to be age rather than writing experience limits to the effective use of discussion of abstract mental

processes and states, and in the ease of controlling the use of different writing processes.

6. Writing plans. The development of planning skills is not yet well understood, but with age there are apt to be many developmental achievements in planning (Pea, 1982) that will distinguish the planning-for-writing competencies of child and adult novice writers.

7. Goal setting and revision. Child novices may have a more restricted taxonomy of purposes than adult novices for the effect they would like to have on their readers. The development of metapragmatic knowledge or rhetorical skills may be a lengthy process, which adults achieve implicitly through their extensive experience in communicative contexts, social exchanges, and through reading.

8. Reviewing. As discussed earlier in relation to Figure 1, reviewing consists of the component processes of "evaluating" and "revising." Evaluating is likely to be a major age-linked bottleneck to cognitive process writing instruction, because it depends on the availability in LTM of standards of evaluation--including the canons of literary genre for good-formedness (aesthetics), the achievement of rhetorical effects (pragmatics), and various metalinguistic judgments about well-formedness (spelling, word choice, grammar, intersentential cohesion). Some of these standards--for example, in aesthetics and pragmatics--are in greater flux and much debated among literary critics.

Although many of these standards can be stated as explicit algorithms for software analysis of texts and allow writers to receive normative assessments of their texts, we know little about whether or not using such systems causes writers to internalize these standards for improving their future writing. Existing systems deal with well-formedness and some aspects of style and genre. For example, IBM's Epistle text-critiquing system uses a parser to determine the syntactic structures of sentences (Heidhorn et al., 1982). Epistle diagnoses subject-verb disagreement, wrong pronoun case, noun-modifier disagreement, nonstandard verb forms, nonparallel structures, overuse of the passive voice, excessive use of negatives, excessive sentence length or clause complexity, and poor readability scores. Its ability to do syntactic parsing also allows for stylistic critiquing. Current document typologies permit critical comparisons between rhetorical structures called for by the genre and the structures present in the document; prompts concerning discrepancies are then presented to the writer (Lance Miller, personal communication, March 1984). Epistle's capabilities include all of those offered by The Writer's Workbench, created at Bell Labs (Frase, 1983; Macdonald, 1983), but the latter system does not have a parser.

Revising techniques, employed to improve what evaluative assessments have found wanting, are numerous (as Elbow, 1981 makes clear) and cognitively complex. Often the writer has available a variety of ways to make her text come closer to her own or her critics' standards. The cognitive operations that guide these choices are not well understood, but we suspect that they are too complex for use with elementary school children whose mental processing capacities, when compared with those of older children and adults, are quite limited.

9. Using writing resources in the task environment. There are also likely to be important differences between child and adult novice writers in their ability to utilize writing resources. These differences may influence the effectiveness of cognitive writing technologies, and should be considered in design processes. We include among "resources" such elements as dictionaries, thesauruses, personal advice from teachers or writers, and other texts (see Figure 1). These age differences may be especially prominent where the technological tool interacts with knowledge, as in the case of word knowledge and how a child (versus an adult) novice would use an electronic thesaurus. But these age differences may emerge in a more general way for metatool skills, which involve learning how to use a new tool, and asking the right questions of people who do know how to use it so that one can learn to use it unaided. In short, there may be age differences in "tool readiness." We do not doubt that "help" option keys on computer-based writing resource tools can support the novice writer in some respects, but we expect that the threshold knowledge required for using help keys will be an age-dependent factor.

Future Prospects of Cognitive Writing Technologies

We have discussed many of the key difficulties that novice adult or child writers encounter, and have alluded to the possible ways in which software tools might address these issues. We will now speculate in more detail on the kinds of cognitive writing technologies that could serve the creative work of the writer.

What are the future prospects for cognitive writing technologies? This question was the major focus of a recent Sloan Foundation workshop attended by representatives of major research projects on writing development and projects engaged in research on and development of writing technologies, senior cognitive scientists, and literary scholars (see acknowledgments, p. 1). Our review of the findings of cognitive weaknesses in writing and the discussions that took place at the workshop help to define some primary issues in the development of cognitive writing technologies.

We must emphasize that we do not offer these remarks as answers to the problems of creating cognitive writing technologies, but as springboards for further thinking about these issues. It is beyond our current scope to determine how the ideas discussed below could--or indeed should--be designed to run on specific systems, or what the features of the interface between writer and computer should be like. Our aim is more modest--to begin a discourse that will ultimately lead to the design of cognitive writing support systems.

Assuming that we take as axiomatic the persistence of writer-based prose throughout the school years and subsequently throughout life for most writers (outlined by Scardamalia & Bereiter, Flower & Hayes, and others), how do we approach the problem? Overall, we feel that what the new technologies must do for writer-based prose problems is to:

- reduce the mental processing loads of writing;

- help writers to achieve voice by encouraging openness and trust in their writing (Green & Wason, 1982; Wason, 1980, 1983);

- help with feedback so that writers can better define their rhetorical problems and high-level writing purposes and goals;

- help writers specify in detail the characteristics of their expected audience that will shape what they say;

- set writing tasks that help writers to exploit their knowledge by providing motivated conditions for writing (e.g., writing to audiences other than the teacher);

- help give writers various writing and revising methods for flexibility across writing tasks (Elbow, 1981);

- facilitate different levels of text representation for planning and revising during writing;

- encourage planning activities throughout the writing process;

- help with feedback on current text so that writers can better organize their content to achieve their writing goals.

At the Sloan Workshop, Carl Bereiter of the Ontario Institute for Studies in Education suggested and elaborated on three basic interventional strategies for fostering writing development: Refinement, Compensation, and Inducement. These strategies do not necessarily require computer technologies for their implementation. The higher

order question is how to teach writing better; then we may ask how new computer-based cognitive writing technologies could help in that process.

1. Refinement. The goal of this intervention is to refine current strategies, that is, to encourage more persistence or "loops" through the processes of writing described in the earlier model (Figure 1). Writers could take more care with and establish better standards for evaluating their texts. This may be accomplished in part by encouraging the use of notetaking, outlining and revision checklists, and other procedural facilitators (Scardamalia & Bereiter, 1983a). All these supports have been shown to have good effects (Scardamalia & Bereiter, 1984), and most could be accomplished with word processors, outline generating programs (e.g., Thinktank, Framework), or prompting programs (e.g., Interactive Text Interpreter [Levin, 1982], Planner, Story Maker).

2. Compensation. The goal of this intervention is to compensate for weak writing strategies. For example, one might encourage pr riting activities to organize content (Collins, Bruce, & Rubin, 1982); goal discovery heuristics, such as self-questioning before writing (Rubin, 1983); peer feedback; self-motivated writing (such as diaries); and writing process conferences with the teacher (Graves, 1983). Good writers are known to use all these techniques, and they lead to better writing.

Software such as Bolt Beranek and Newman's Quill microcomputer system (Collins, 1983; Collins, Bruce & Rubin, 1982), and programs currently being used in writing development studies at the Ontario Institute for Studies in Education, help to promote text planning. Existing telecommunication networks have also been effectively used to support peer feedback and motivate the writing and revising process (Levin & Boruta, 1984; Levin, Boruta, & Vasconellos, 1983; Levin, Riel, Rowe, & Boruta, 1983; Riel, 1983):

> Computers were used to create functional writing environments, those with a purpose and audience for their work. When students realized that other people would read their work, not to evaluate it, but for its content, they took a very different approach to writing and actively engaged in the revision and editing of their own writing and the writing of their peers. (Riel, 1983)

Process conferences between teacher and student around a piece of writing at the computer are also proving to be a powerful environment for learning to write better. But they are not viable solely because of current computer technologies; they require good writing teachers.

To encourage students to reflect on what they have written, "conferencing" software would need more intelligence than is now possible. Such "intelligent" computer-assisted writing instruction and adjunct uses of interactive videodisc systems (e.g., to model expert writing strategies for the student at developmentally appropriate junctures) may be useful for future compensation interventions, but no advances are imminent on this front.

3. Inducement. The goal of this intervention is to induce writing strategy development. One could conduct direct instruction in college-writing expert techniques, build peer and teacher strategy modelling (e.g., think-aloud protocols) into curricula, use consequential tasks and games inducing rhetorical goal setting (e.g., provide final sentence giving goal to work toward, or dictating sentences one at a time for kids to find a written framework for).

CAI techniques might be used for direct instruction, and interactive videodiscs, yet to be designed, might be used for expert writing strategy cognitive modelling. Consequential tasks and games are available today (Scardamalia, Bereiter, & Fillion, 1981).

On another level, Levin and colleagues (1983) demonstrated that, when more functional writing environments were created through computer-mediated interpersonal communications on networks, students were compelled to care more about their writing and the effect it had on readers, and were thereby more inclined to learn better writing techniques. But, again, in order to achieve maximum results, it is necessary that rich technological environments and the desire to write better be wedded with good writing instruction.

Here, we would like to distinguish between short-term and long-term computer-based writing technologies that would take us further along the road toward cognitive writing technologies. In the near future, we envision:

1. Cognitive writing technologies that allow for the editing of text, paragraph, and sentence-level representations rather than specific words (Bruce, Collins, Rubin, & Gentner, 1983; Frederiksen, 1983). For example, schematic argument structures are preeminent for expository writing--the working structure of the literature of law, philosophy, science, and the classic essay form. The familiar structure is introduction, background, issue definition, statement of thesis to be proven, arguments for and against the thesis, refutation of opposing arguments, and summation. Other text-level forms that could be supported by specific technologies are the "pyramid form"

found in news stories, and "narrative forms," which have been the focus of much psycholinguistic work on story grammars.

One problem that writers have with revising is stepping above word and sentence revision to reorganize higher level units, such as paragraphs, to better correspond to canonical text-level forms, such as argument. Novice writers do not often work with high-level text representations in their revisions (Faigley & White, 1981; Sommers, 1980). Butturff and Sommers (1980) have captured the low-level revising to which most students limit themselves:

> We would...argue that encouraging students to regard re-writing as a process that is limited to altering words, sentences, and paragraphs will actually interfere with their understanding of what happens when experienced writers write. Indeed, the problem most often faced by freshman revisers is that their strategies for rewriting are restricted to questions such as: Can I find a better word or phrase? Can I cut out any excess words? Have I expressed myself badly?
>
> What these students need is an understanding that rewriting must go beyond fixing up a word here and a sentence there....Freshmen need, in short, to develop a sense that rewriting is not a staged last act, but a process that itself consists of a series of cycles.

Technologies could make possible the explicit editing of high-level representations. Software could be created to help reflect back to the writer the text created thus far at representational levels not previously accessible without great effort (e.g., topical outlining, argument structures, decision paths, networks, issue trees). Computer tools could be designed to facilitate the formidable cognitive demands of such high-level text editing. Appropriate use of such a system would also require good instruction because novices will need to understand the advantages of moving text around and different level text representations. In particular, they need to be aware of options, for example, that their intentions are distinguishable from the text, not fused.

As a specific example of a structural tool, Frederiksen and Bracewell indicated at the Sloan Workshop that it would be possible to create software that would allow the microcomputer to parse text by surface topical structures through looking at first constituents of all clauses. The software could display these topical structures and the writer would know what topics were treated whether and how they were elaborated, and whether the text jumped (as it generally should not)

from topic to topic. This would also help the writer to make decisions about what is given or new for the reader in the information she has presented in her text.

2. Technologies that help to teach or, in the case of experts, support the use of information acquisition and management skills for compiling materials to write about. Such technologies would have to build on the logic of question asking, and recent developments in designing database management systems guided by what we know about human memory retrieval processes (Tou, Williams, Fikes, Henderson, & Malone, 1982).

3. Technologies that model cognitive processes of writing by writers of different skill levels. The goal would be to raise a novice writer's awareness of writing processes--especially their cyclical rather than linear nature--and increase his or her repertoire of writing and revising methods, thus making for greater flexibility. In short, we want technologies that, for instructional purposes, can make the cognitive processes of better writing more "visible" for analysis or imitation. For example, with an interactive videodisc we could exemplify key writing processes at major decision points by creating docudramas of a real writer, who articulates aloud her metacognitive activities as she writes and revises.

4. Technologies and computer-based instructional methods for moving easily between reading and writing (and rewriting). Reading to write and writing to read are important reciprocal relations that are central to the development of writing skills. Databases of model examples of different writing genres could be created, and reading such sources and emulating their writing style could provide valuable experience.

5. Technologies that aid the browsing and structuring of materials a writer has created in loosely structured text production (Brown, 1982), or "freewriting" (Elbow, 1981). Some suggestive aspects of such a computer tool are provided by Weyer's (1982) "interactive book," created at Xerox's Palo Alto Research Center. It is based on a social studies text and comes with a browser for finding information in the text on specific topics; as a topic is selected, the text on that topic appears, and the relevant words are highlighted.

6. Technologies with special utilities to support writing according to different methods (Elbow, 1981), in order to support flexibility of writing methods for both novice and expert. These could consist of interactive prompts that have the writer define the type of writing task, which can then be loosely linked to advice about effective writing methods ("If you are writing a memo, and have little time,

one useful method is..."). Different computer writing worksheets could be designed to support each of the methods.

7. Technologies that preserve the revisionary history of a written document. Such process-oriented writing tools could be created today (Brown, 1982), would be very helpful for teachers and researchers, and could be useful for the writer if contexted appropriately. One could unpeel successive layers of revisions in efforts to understand how a text structure is built, deconstructed, and rebuilt, or to find text segments in earlier drafts that were deleted and later found to be usable.

In the longer term, useful writing technologies might include:

8. Expensive-to-develop general resource tools that provide a substrata from which specific cognitive writing technologies could be built (e.g., dictionaries, thesauruses, grammars and text parsers, encyclopedias, genre banks, and other useful databases), or which could be used as components of specific writing tools. Of particular utility would be such tools as automated dictionaries, organized for use during writing in ways compatible with human processes of lexical access (Miller, 1979).

9. Expert critics of text that take advantage of advances in artificial intelligence work on natural language understanding, and which encourage the writer to become more reflective and critical of her writing as she edits and revises.

10. Developmental writing tools which are self-modifying in that they take the shape and allow the options that the writer would find most useful in light of her writing skills and style (Brown, 1982).

11. Genre-specific writing tools, with different utilities appropriate to streamlining the cognitive and production ends of writing to the specifications of the genre (e.g., haiku poems, business letters, essays, movie reviews, political news stories, experimental reports, grant proposals).

Actualization Problems for Successful Cognitive Writing Technologies

Side by side with these rosy prospects are the problems that arise in thinking about the kinds of cognitive writing technologies we are proposing. In particular, the systems design issues are quite complex. We recognize that all we can do here is to list concerns in the hope that they will help to organize thinking and discussions aimed at solving them.

Human psychological factors are primary, since the systems design process will be interactive and didactic, playing prototype system characteristics against user reactions and usability (Gould & Lewis, 1983). What will the systems do? How can the cognitive interface(s) between a writer's creative forces and the computer's writing tool capabilities be best arranged? How will the constraints of the settings in which such tools will be used (e.g., classrooms vs. offices vs. homes) affect their design features (Hawkins, Kurland, Char, & Freeman, 1984)? These are major issues that must be resolved, but let us now discuss more specific concerns.

We will first try to break down issues in terms of the local concerns that directly affect the writer during use (problems of the cognitive mechanics of writing technology systems). Then we will discuss the broader concerns indirectly affecting users of cognitive writing technologies and how they interpret/think about the tools (and, indeed, whether they think about or use them at all). Finally, we will earmark what appear to be major issues for research in the near future --significant "unknowns" about the development of writing processes-- which could have major influences on cognitive writing technology systems design.

Local Writer-Related Issues

A major issue raised by some participants of the Sloan Workshop is the potential proliferation of writing tools for the many different kinds of writing, writing styles, and skill levels. As a result of this, the writer may have what Chip Bruce has described as a "metatool" problem, that is, a problem arising when special cognitive skills are required just to know when to use a specific tool and for what purposes. We expect that such a plethora of possibilities would be problematic even for the highly skilled writer. For the novice writer, we would have to ask when and at what levels of writing skill it would be most useful to introduce specific tools. To take one example, current electronic thesauruses offer on-line access to synonyms during text composition. While this tool may be useful for reminding the expert writer--who already knows the meaning of the related terms--which one more accurately captures the nuances of meaning he or she wishes to convey, it may be inappropriate for a novice. This tool alone may not enable the novice to evaluate the suitability of words offered by the thesaurus for the meaning he or she wishes to express.

A problem related to the metatool problem is making sure that the new computer-based writing systems maintain "writing ballistics." An author wants to use transparent writing tools. They should be maximally helpful and, at the same time, unobtrusive and free from

distractions; that is, writing choices should take preference over technological choices. This is easier said than done, and the ballistics problem is a variable one, depending on the writer's skill level. Solving this problem may be particularly difficult in creating cognitive technologies for novice writers, who are having enough trouble managing the task of writing without having to contend with the problem of choosing the appropriate tool. Technology should facilitate the writer's (whether novice or expert) free flow of ideas, not further complicate the writing process.

Another potential but (at least in principle) avoidable danger in creating writing tools for the novice is the use of automated "text critics," such as IBM's Epistle program and The Writer's Workbench from Bell Laboratories, which flag textual errors of various kinds. It is widely recognized that too much concern with whether or not one is going to make errors inhibits the creative process and deemphasizes the use of the personal voice in writing. An overemphasis on reader-based prose can hinder writing progress (Elbow, 1981).

Broader Issues: Society, School, and Family

There are many issues beyond the "purely cognitive" that will have an important impact on whether cognitive writing technologies will be viable tools for anyone but their creators. In particular, societal attitudes about writing--and especially their embodiment in our educational system--will decide how cognitive technologies for writing will be used. It cannot be ignored that writing instruction and the ways in which people have learned to write over the centuries have largely determined how people think about writing. And how writing activities are currently organized in our schools, at home, the workplace, or elsewhere will serve as major constraints on the functionality of cognitive writing technologies. Habits and ways of thinking about writing--when it is done, how, and by whom--will, to some extent, be resistant to change. Furthermore, attitudes toward computational systems will influence the acceptance of computer-based cognitive writing technologies. Although we cannot do justice to a treatment of these issues in the confines of this paper, we do not want to give the impression that they are not deemed important. In fact, for many at the Sloan Workshop, these were primary issues to be thought about early enough in the design process to influence the shape of the software system.

In particular, there is the all-important question of the purpose and motivation of the writer that, as we have seen in our account of the cognitive science of writing, fuels the writing process. These "start-up" issues--what will cause the writer to begin writing and provide him or her with the cognitive momentum to keep on writing, to evalu-

ate and revise, or to desire more highly developed writing skills--are at the heart of our broader concerns. In other words, it is one thing to know how to develop writing expertise through cognitive technologies for writing; it is quite another--perhaps even of a different order--to be able to set these processes in motion by getting a potential writer onto these developmental tracks.

How can we provide functional learning environments for writing that will attract the novice? How can we encourage the all-important attitude of "trust" in writing--the capacity to tolerate one's own written expressions of thoughts and feelings on paper without distorting them to fit some preconceived ideal or fashionable style (Green & Wason, 1982; Wason, 1983)? We cannot answer these questions, but researchers are today making some promising inroads on these problems. Some critical links to be forged are those between oral literacy--in which people tend to speak in their own distinctive voice--and written literacy. We wish to sketch out these levels of broader concern beginning with the Society, then the School, and finally the Family. All these formative forces can serve as either scaffolds or constraints on whether a person who <u>can</u> learn to write (and read) does so or not:

> Research...suggests that all [physiologically] normal individuals can learn to read and write, provided they have a setting or context in which there is a need to be literate, and they are exposed to literacy, and they get some help from those who are already literate. (Heath, 1980, p. 130)

<u>Society</u>. In order to help change students' attitudes about writing, we need a literate society in which writing and reading are seen as valuable and pleasurable. Such a society would promote the idea of writing not only as expressive but as analytic--something to be critiqued, discussed, reflected upon, and improved. Without such activities, there is too little spontaneous reviewing of texts for other than low-level linguistic standards; the writing that develops does not go beyond writer-based prose. At the same time, however, these critical activities need to take place in an atmosphere of trust. Texts are not right or wrong, but better or worse in relation to fulfilling the author's goals, and critical judgments are thus seen as part of an interaction between thought--both one's own and others'--of a generative nature (Wason, 1983).

As part of this society, we need support systems of listeners, critics, and respondents; in short, a literate community. We should be wary of moving, as some people have, from "is" to "ought" by observing that "because writing does not appear to be used so often in our society except by an elite, why encourage it?" For one thing, people

might be much more frustrated by their inability to write if they knew the powers it could grant them. Most people feel the need to write persuasively throughout life, but feel little connection between what that task calls for and what they learned in school while writing according to a teacher's dysfunctional specifications. Insofar as writing is a peripheral activity, it will always need a good deal of instructional support, and we predict that writing on computers at home will not happen just because the computers are there.

Schools. We cannot review here how writing is predominantly taught in our schools; suffice it to say that, too often, writing instruction consists of copying from blackboards or from teacher dictation, and is not the creative, cyclical, multi-staged act we have assumed throughout this essay. There are three primary classes of problems with schools: teachers' attitudes about writing, the status of the child-as-writer, and helping students to mobilize openness and trust in their writing.

One class of problems stems from teachers' attitudes toward and involvement with writing activities. If teachers do not value writing as a cognitive activity in which anyone can engage, why should their students believe they can learn to write well? A major problem is that not all instructors, even in college, think of themselves as writers, and many do not have available a metalanguage for advising students on the problems they encounter with rhetorical prose. We can expect this situation to improve with the increasing use of instructional texts based on the cognitive research surveyed in this essay (e.g., Flower, 1981). In the meantime, teachers' self-perceptions and their misunderstanding of writing processes will inevitably influence their students' reactions to the introduction of cognitive writing technologies in classrooms.

Teachers, too, need more than just good computer-based cognitive writing technologies. Writing instruction, in itself a cognitive writing technology, must be wedded to the computer-based, instructional writing tools we propose. Student-instructor writing conferences have been very successful, and no "intelligent" computer-based critic today could even hope to approximate the skills of a good writing teacher. As Bereiter has noted, a student's writing progress depends on the quality of the writing program. Schools are not generally analytical about texts; yet learning to write well presupposes the acquisition of critical standards.

Teachers as well as children must have a cognitive process model of writing, one that emphasizes the flexibility of writing processes and the need for each writer to find the writing methods that best suit him or her. This diversity model of instruction would give teachers a

different attitude about reviewing students' writing; each draft could be seen as one stage in the development of a work, in which students are constructing in their minds the standards of the adult literary world that the teacher implicitly expresses through his or her supportive criticisms.

The second class of problems has three main aspects, all involving the status of the child-as-writer: the kinds of writing practiced, writing for effects in readers, and writing for voice.

The kinds of writing children practice is an important issue. More writing activities are needed where children's purposes and interests serve to fuel the writing process. As Kenneth Burke has put it, people need to get "heated" to write, even "psychotic," in the positive sense of being obsessed with their topic. As one way of embodying these goals, larger literary works such as stories or books could be imagined, discussed, designed, and created by child writers, to make the writing take place over extended periods and be more like writing that occurs in the world beyond the school walls.

Furthermore, like most adults, children need to do writing that--like the oral mode of speech that comes so naturally to them--has effects. Student writing should be able to move things or people in the world, rather than merely meeting short-term instructional goals. We need to make a greater effort in schools to have a student's goals rather than a teacher's commands serve as engines for writing. As many have recently pointed out, motivating children to write in early writing programs can be facilitated greatly by carrying features of oral communicative contexts into the classroom, such as social interaction and sharing of experiences (Dryson, 1983; Graves, 1975, 1983; Tannen, 1982).

There are already many activities that demonstrate children's use of computer technologies to write for effects. For example, studies of children's writing on electronic networking systems at the University of California at San Diego demonstrated that, when students wrote for a real audience instead of in response to a school assignment, they concentrated much more on formulating messages appropriate to members of the reading audience and their background knowledge (Levin, Riel, Rowe, & Boruta, 1983).

A third and related aspect of the problem of the status of the child-as-writer is that schools should encourage and value the child's expression of "self" and individuality through his or her writing. A high priority of writing instruction should be to help children to develop their own style and voice. Developing "voice" in writing deserves special emphasis, since it is a quality widely acknowledged

to be essential for writing to have "life" and interest--key qualities in capturing a reader's attention and getting effects. The masterful German writer and literary critic, Karl Kraus, was quite forceful on the centrality of voice:

> There are two kinds of writers, those who are and those who aren't. With the first, content and form belong together like soul and body; with the second, they match each other like body and clothes. (Auden & Kronenberger, 1981, p.275)

It is possible that problems with attaining and maintaining voice may be exacerbated by computer-based writing tools that serve as "critics" of text in terms of such standards as sentence length, word complexity, and other evaluations. Howard Gardner has described a worst-case scenario of using computer writing tools that "evaluate" text. We might see the emergence of a homogeneous style of writing that is of consistently low quality--its life, individuality, and voice squeezed out by the normative critical standards of the computer.

Whether or not one has such fears, the rhetorical point is clear: we must ensure for cognitive writing technologies that means be provided to facilitate the emergence of the writer's distinctive voice. A major way to do this will be to recognize that written voice is rooted in oral voice. Kenneth Burke has argued that people should be taught to speak well first and then to write, and that we should then emphasize not only eye-reading from the screen (and page) but voice-reading--going back and forth from the orality of the body to the structures of the written language, so as never to lose the voice of the body "behind" the text (cf. Elbow, 1981). It is currently unknown what processes talented writers go through and what knowledge representations they possess that allows them to get control over their voice, and research addressing this question would be very helpful. It does appear likely that school tasks promoting oral fluency will help in this respect.

If the first two classes of problems with schools were solved, the third would probably take care of itself. Children need, as Wason (1980, 1983; Green & Wason, 1982) has so elegantly argued for novice adult writers, to "mobilize their trust" in their writing, to have confidence in what they say, in the messages of their voice as it develops through their writing. In order to give children confidence in their writing processes, they need to know that learning to write takes time, but that with practice, reading of genres, and careful attention to their work and what others say about it, their writing will continue to improve. To feel this confidence, it is important that evaluation, revision, and other writing activities that involve the

teacher's tutorial efforts be done in an atmosphere of friendship and collegiality rather than in a reproving, inimical manner.

Family. We also must point to the family as influential in determining a student's values concerning writing (Heath, 1980). Although studies of writing development have yet to look seriously at home literacy activities as a research variable, there have been many discussions of how family environments appear to be related to cognitive development (e.g., Walberg & Majoribanks, 1976). If no one in a family considers writing or reading to be important, we expect that children will be less likely to choose to write or find meaning in writing activities. We expect that children will be more likely to write, and to learn to write well, both at school and at home, if they are members of literate families in which writing is valued, practiced, and discussed. In short, a fertile environment for writing development often includes the family. Ideally, parents could provide such meaningful role models as writers that their children would have an intrinsic interest in and be able to externalize their own reflective processes during writing.

Some Research and Non-Research Issues

Many research agenda might contribute to the knowledge we need to create effective cognitive writing technologies. In particular, further work on the development of various components of writing skills is a high priority, and recent interest in charting the influence of affective and motivational issues on writing is an important direction. We still know very little about what distinguishes the child from the adult novice writer, and how life histories with literacy activities constrain a writer's affective and creative attitudes toward writing. Beyond these basic concerns, one other area seems to be particularly worthy of research attention.

Since cognitive writing technologies, as we have argued, are likely to require good writing instructors to be effective, we need to find out what superior writing teachers and critics in fact do to improve a student's writing. What are the practices of a good writing instructor? What would think-aloud protocols of the expert writing instructor working with novice writers reveal about the coaching process? How do good writing instructors diagnose the student's problems? How do they sequence and time their advice, and decide what to focus on in their constructive critiques? How do they encourage a novice to develop his or her distinctive voice? In the absence of such research, we have little hope of replicating expert teaching techniques in the instructional aspects of future cognitive writing technologies. Outcomes of such studies will be needed to inform the design of future "expert" and "intelligent" systems for computer-

assisted writing instruction, and possibly the computer-based textual critics that will encourage further development of expert writers' skills.

In this respect, we are encouraged by the Socratic systems for tutoring causal knowledge and reasoning developed by Collins and colleagues (Collins & Stevens, 1982), which incorporate rules for tutorial interactions derived from careful observations of the dialogues of expert inquiry method teachers. Of paramount importance in these endeavors will be solving the problems involved in delivering the coaching feedback offered by the system, which have been fruitfully discussed in relation to work on ICAI environments (see Sleeman & Brown, 1982). Too much feedback, or feedback at the wrong time, can hinder rather than aid the writing process.

These points may apply to the expert writer using cognitive writing technologies. We know little about how mature writers continue to improve their writing skills, yet analyses of literary development among writers, poets, and philosophers are commonplace in the critical literature of the humanities. How are such advances accomplished? How could they be encouraged by design features of computer-based writing technologies? Once the cognitive supports of various component processes of writing are provided, expert writers may be able to discover for themselves how to use them to improve their writing. Given how little we know today, it is only possible to raise the questions.

From the perspective we have adopted throughout this essay, it should be clear that we regard as the major issues surrounding the development of cognitive writing technologies those that focus on the writing, not the technology. While some human factors research is needed to better ascertain what ideal screen layouts, keyboard configurations, or command structures people can most easily or effectively use, the most central issues concern what the developing writer knows or understands about writing, not the technology's intrinsic capabilities.

In contrast, much of the current research on writing technologies fixates on the technology itself. Two non-research issues receiving an inordinate amount of attention in recent work are: (1) Can young writers learn to use a keyboard for writing? (We have known since the 1920s that the answer is "yes," and that they write more and with greater enjoyment); and (2) Does writing with a word processor make students revise their texts more? This latter question is meaningless without reference to a particular kind of writing and a specific instructional environment and teaching approach. It also ignores a much more interesting and important question: If students are revis-

ing more, at what level are they making their revisions and toward what ends?

Coda

In this essay, we have highlighted what promise to be productive directions in the growing collaboration between those who study how writing skills develop and those who create computer writing technologies. But, just as importantly, we have seen that there are much broader issues that must be considered if we are to end up with writing technologies that can be used effectively, particularly in the formative years of writing education in schools. At least four major variables need to be considered: (1) the current writing skills of an individual, and the structure and function of their component cognitive processes while engaged in writing; (2) the affective-motivational complex that defines an individual's attitudes toward and interest in writing activities; (3) the instructional environment--including teachers, peers, and the larger framework of society; and (4) the writing technologies, including computer tools, that are available. Very little work thus far has addressed the terrain of writing development in these terms.

Although they have been our major focus, forging new computer technologies that strengthen the various cognitive processes central to developing good writing is but one part of the equation linking writers to better writing. Teachers need to know more about how to foster writing processes, whether or not they are armed with the new technologies. The literacy practices and attitudes of society and parents may also be sending students significant (and mixed) messages about the importance of good writing. And the affective and motivational side of writing activities, although little studied, appears to play a major role in the attainment of writing voice, and whether writing practices are even begun.

Writing is an intricate and important problem that is finally beginning to attract the attention it warrants. The imbalanced focus on how people learn to read existing texts rather than on how they can create their own is at last shifting. Using the symbolic capabilities of the computer to serve writing development promises to be one of the most exciting and truly personal uses of the computer. If, as Wittgenstein noted, writing can help ideas develop, why cannot computers help writers develop? We think there is reason to be optimistic about the dialogues on writing that are beginning to take place among software designers, writers, psychologists, and educators, and hope that they will lead to an understanding of how best to use computer tools to create cognitive writing technologies.

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EasyWriter. Information Unlimited Software, Inc., 2401 Marinship Way, Sausalito, CA 94965.

EMACS. Digital Equipment Corporation, 200 Baker Avenue, West Concord, MA 01742.

Framework. Ashton-Tate, 10150 West Jefferson Boulevard, Culver City, CA 90230.

ICE. University of Illinois, Champaign, IL.

Interactive Text Interpreter. Interlearn, Inc., P.O. Box 342, Cardiff By The Sea, CA 92007.

Planner. Bolt Beranek and Newman, Inc., 10 Moulton Street, Cambridge, MA 02238.

Quill. Bolt Beranek and Newman, Inc., 10 Moulton Street, Cambridge, MA 02238.

The Random House Thesaurus. Dictronics Publishing, Inc., 362 5th Avenue, New York, NY 10001.

Scripsit. Tandy/Radio Shack, One Tandy Center, Fort Worth, TX 76102.

Story Maker. Bolt Beranek and Newman, Inc., 10 Moulton Street, Cambridge, MA 02238.

TECO. Digital Equipment Corporation, 200 Baker Avenue, West Concord, MA 01742.

Thinktank. Living Videotext, Inc., 450 San Antonio Road, Suite 56, Palo Alto, CA 94306.

UNIX. AT&T Bell Laboratories, 6 Corporate Place, Piscataway, NJ 08854.

VisiWord. VisiCorp, 2895 Zanker Road, San Jose, CA 95134.

The Word Plus. Oasis Systems, 2765 Reynard Way, San Diego, CA 92103.

WordStar. MicroPro International Corporation, 33 San Palo Avenue, San Rafael, CA 94903.

Writer's Workbench. AT&T Bell Laboratories, 6 Corporate Place, Piscataway, NJ 08854.