Chapter 17

The Effects of New Technologies on Writing and Writing Processes

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In a recent article in *The Washington Post* Sennett (2004) discussed the agonized reflections of a college student about whether her use of e-mail rather than the more casual instant messaging had scared away a potential date by conveying too much sense of commitment. In the high-stakes rituals of dating, where e-mails are edited by friends for the proper breezy tone before sending, her friends concluded that the e-mail had definitely been a mistake.

Electronic technologies are changing the forms by which people communicate with each other and understand the world. Changes in technology have and will continue to change the nature of literacy practices in society, and the cognitive and social skills needed to be considered fully literate. The process did not start with computers. Radio, television, and the movies dramatically altered the ways in which we receive news, entertain ourselves, consume goods, choose heroic figures, elect our leaders, and understand our culture. These popular media have had limited direct impact on schooling, though they may have had substantial indirect effects. Computer technologies may have a more direct influence on schooling and on literacy for two reasons. First, the integration of text and other media in hypermedia and the Internet means that schools, charged with responsibility for the important business of teaching reading and writing, cannot ignore them as they did television and the movies. The integration of text with graphics, video, and sound may encourage schools to expand the concept of literacy to include a variety of media. Second, electronic technologies engage students as writers or producers rather than just as readers or consumers. From publication of class newsletters to e-mail projects to hypermedia web pages, to blogs and zines, computers offer students opportunities to create new types of documents. At the same time, they are changing the ways in which traditional text is produced. New technologies promise to become increasingly important in our schools as tools for inquiry and learning, as well as means for communicating and composing.

In considering the impact of new technologies on writing, it is useful to begin with recent scholarship on the impact of writing on cognitive and social processes. Writing is itself a technology, a combination of a symbol system and various physical means of production, that makes possible the durable representation of language. Olson (1995) argued that written language, by capturing and communicating words with precision and separating them from the context of production, affords the opportunity to think in a more abstract and decontextualized way. The invention of the alphabet, which made literacy possible for more than the few, and of the printing press and paper, which supported wide literacy, had dramatic impacts on the nature of thinking in society—

supporting the development of a more rational approach in all fields of knowledge. Arguing against Olson's thesis, Scribner and Cole (1978) demonstrated, through study of users of an informal, nonschooled script used primarily for personal letters, that rational, decontextualized thought is not an inevitable consequence of the development of literacy but rather is a consequence of schooling. Thus, writing affords the opportunity for the development of more abstract thinking, but the actual impact on cognitive processes depends on the social context of use. This general principle applies to new technologies as well. New technological forms of writing afford opportunities for the development of cognitive skills and social interactions, but the actual effects of the technology depend on complex interactions among the technology, the social context, and individual users.

There is no shortage of theoretical work on the transformative effects of technology on literacy. Bolter (1998) argues that hypermedia, of which the Internet is the prime example, will have revolutionary effects on literacy for two reasons. First, the multilinear nature of hypertext challenges the rhetorical foundation of teaching writing (i.e., presenting a coherent point of view, with supporting arguments, by encouraging the presentation of multiple viewpoints). Second, hypermedia place greater emphasis on visual images than on verbal text, which will have dramatic effects on how knowledge is represented and manipulated mentally. Purves (1998) goes further, declaring that the impact of the digital media on literacy will have a historical weight equal to the invention of alphabetic writing and the printing press. He argues that the visual and organizational features of digital information convey meaning beyond the words. In particular, the emphasis on visual imagery will deemphasize the importance of language to meaning, and hypertext links will lead people to think in multidirectional rather than hierarchical ways.

In contrast, Bruce and Hogan (1998) argue that technology has quite variable effects depending on how it is embedded in a social context. Literacy technologies are ideological tools that are designed, accessed, used, and interpreted to further purposes that embody social values. In a classroom setting, the technology, the teacher's instructional methods, and student experiences will all interact in ways that determine the effects of technology as an innovation. Similarly, Perkins (1985) claimed that various media and technologies promote and require different types of thinking, because they use different symbol systems and afford various types of interaction. Regular use of any technology has effects on cognition that can be subtle and occur without awareness. However, how the affordances of technology are realized depends on conditions such as instruction, expertise, background knowledge, and design of the tools.

Despite the broad and interesting theoretical claims, empirical research on the cognitive and social effects of technology on writing is quite limited, and the results of that research are mixed. My purpose in this review is to examine empirical research on the impact of new technologies on writing and learning to write. Writing is defined broadly to include creation of hypertext or hypermedia, as well as traditional linear text, but not so broadly as to include video and film production. The review is limited to studies focused on writing, not on reading or the effects of technology on acquiring knowledge. It is also limited to work done in educational contexts, omitting the growing literature on out-of-school writing and popular media. Finally, it is limited to elementary and secondary education.

I begin the review by considering the effects of technology on producing traditional linear texts, including the cognitive processes involved, the development of skills, and how social interactions in instructional settings modify these effects. Sections address word processing, computer support for writing and learning to write, and assistive technology for struggling writers, then review the emerging research on composing hypermedia or hypertext. Finally, the review considers the effects of computer-mediated communication as it affects writing, including intercultural communication projects and the use of networked communication in writing classes.

Word Processing

One area of technology and writing that has seen extensive research is word processing. It was a common early application of comput-

ers in schools and is probably the most widely used application in the general population as well. It seems well adapted to contemporary theories about writing as a cognitive process involving recursive cycles of planning, drafting, and revising. Furthermore, it supports social processes by enhancing opportunities for publication and collaborative writing. A large number of studies of word processing were published in the late 1980s, followed by a slower but steady stream of publications to the present.

Two meta-analyses of the research have reported moderate positive effects of word processing in writing instruction on the length and quality of compositions. Bangert-Drowns (1993) found small to moderate effect sizes for quality (0.27) and length (0.36). [Note: Unless otherwise indicated, all effect sizes (ESs) reported in this chapter represent the common metric of mean difference divided by the standard deviation.] Though elementary, secondary, and college students were included, effects were not related to age. Interestingly, positive effects were found even when posttests were administered in handwriting, suggesting that whatever students had learned from instruction with word processing transferred to writing without computers. In a review of similar research since 1992, Goldberg, Russell, and Cook (2003) reported somewhat larger ESs for quality (0.41) and length (0.50).

Some evidence indicates that effects on quality are stronger for struggling writers than for average ones. The small effect on quality reported by Bangert-Drowns (1993) is better viewed as a combination of a moderate ES for nine studies of remedial instruction for struggling writers (0.49) and a nonsignificant ES for 11 studies with average writers (0.06). A few studies have shown positive effects of word processing in combination with instruction for students with learning disabilities (for a review, see MacArthur, 2000). It is important to note that few of the studies covered in these reviews effectively controlled for instruction to isolate the effect of the technology. Thus, it is probably more accurate to say that word processing in combination with instruction adapted to the technology had positive effects.

An important practical concern reflected in recent research is the impact of word processing or its absence on student performance on accountability tests. Wolfe, Bolton, Feltovich, and Niday (1996) compared test essays written via handwriting and word processing by high school students with high, medium, and low experience with word processing. No differences were found for quality or length for students with high or medium word-processing experience, but students with low experience wrote shorter, lower quality essays with word processing. Russell (1999; Russell & Plati, 2001) studied high school students taking tests involving multiple-choice questions, and paragraph and essay-length responses from state accountability tests on the computer, or with paper and pencil. No differences were found for multiple-choice questions, but students who were accustomed to writing with a word processor and had competent typing skills (20+ words per minute) performed substantially better on written responses when they used the word processor (ESs from 0.5 to 0.9). One of the studies (Russell, 1999) included students with a range of measured typing skills; students with below average typing scored significantly lower (ES = −0.4) with word processing, while those with above average typing scored significantly higher (ES = 0.5). Students who are used to writing with word processors may be at a substantial disadvantage if not permitted to use them on high-stakes tests.

Research on the impact of word processing on revising and other writing processes has been mixed. In early reviews, Cochran-Smith (1991) reported that word processing for elementary students resulted in more surface revision, but Hawisher (1987) and Bangert-Drowns (1993) found that results were too varied to draw any conclusions. One reason for conflicting results is variations in how revisions were measured. If revisions are only counted between drafts, then the extensive revisions often made during drafting with a word processor are missed. Another possible reason for variation in instructional studies is whether and how revising was taught. Experimental studies that compared handwriting and word processing without instruction with middle school students with learning disabilities (MacArthur & Graham, 1987), college students (Kellogg & Mueller, 1993), and expert adult writers (Van Waes & Schellens, 2003) have generally found more revisions during drafting with

word processing, with most of those revisions focused on minor changes that did not affect meaning.

Early predictions that word processing would free writers from concern with the mechanics of text production and enable them to focus on higher level concerns (Daiute, 1986) have not been supported. In fact, the evidence on revision suggests that word processing increases attention to minor editing. Overall, the research is consistent with a view of the word processor as a flexible writing tool that has modest effects on writing processes, particularly revision, and that affords opportunities for learning if combined with effective instruction. Thus, the effects are largely dependent on the context in which word processing is used.

Computer Support for Planning and Revising Processes

Since the early days of research on word processing, educators have tried to design software that would supplement word processing by direct support of planning and revising processes. Most efforts have been based on cognitive models of composing processes (Hayes & Flower, 1980) and on Bereiter and Scardamalia's (1987) concept of procedural facilitation, or temporary supports to guide developing writers in using more sophisticated cognitive processes.

The most positive results to date were found in a study by Zellermayer, Salomon, Globerson, and Givon (1991). Their Writing Partner provided fairly extensive metacognitive support for planning, drafting, and revising. The planning tools asked students to answer questions about rhetorical purpose (e.g., Are you trying to persuade or describe?), topic, audience (e.g., Is your audience experts or beginners on this topic?), main ideas, and key words. While students worked on their draft, metacognitive questions appeared in random order, prompting students to consider purpose, organization, and elaboration; these prompts drew on information from the planning segment (e.g., descriptive or persuasive purpose). The revising questions included not only generic revising concerns but also drew on planning (e.g., asking about evidence, if the purpose was persuasive). High school students were randomly assigned to one of three groups: writing partner with solicited guidance (SG) or with unsolicited guidance (USG), or regular word processing control (C). Both experimental groups received identical planning and revising support; the only difference was that the USG group saw the drafting prompts at random intervals without asking for them, whereas the SG group was directed to check the prompts by typing a special key. Pretest and posttest essays were written by hand without support in order to test the theory that the metacognitive support would be internalized. Both on essays written with support and on handwritten posttest essays, students in the USG group earned substantially higher quality ratings than the other two groups, which did not differ from each other (posttest ES about 1.5). The reason for the difference between the SG and USG groups is not clear. Planning and revising support were identical, and both groups saw about the same number of prompts during writing and recalled the same number of prompts on a posttest. Unfortunately, no further research was conducted with this tool to replicate or extend the findings.

Bonk and Reynolds (1992; Reynolds & Bonk, 1996) conducted two studies of a similar program that provided metacognitive prompts on planning and revising during composing. Students had a list of the eight types of prompts and could access them at any time; there was no unsolicited guidance condition. In the first study (Bonk & Reynolds, 1992), middle school students wrote three essays using the support tool and took a posttest with a regular word processor; a control group wrote three practice essays with a word processor. No effects were found on number of substantive revisions or on the quality of essays produced with support or on the posttest. In the second study (Reynolds & Bonk, 1996), first-year college students in a composition class received 9 weeks of instruction on planning and revising and were then assigned to experimental and control conditions, and wrote a paper using the support tool or a word processor. Students made significantly more substantive revisions and received higher quality ratings with the support tool; however, there was no correlation between the number of revisions and quality. No measure of transfer to writing without support was gathered. Differ-

ences in age, instruction, and outcome measures make it impossible to interpret the reasons for the different results across the two studies.

Rowley (Rowley, Carsons, & Miller, 1998; Rowley & Meyer, 2003) reported a series of studies of a computer program that provided prompts to support three aspects of writing: brainstorming ideas, setting goals and organizing ideas, and revising. All four studies were large quasi-experimental studies (500–1,200 students) in middle and high schools but with relatively small amounts of program use (6–15 hours over a semester or year) and poor treatment fidelity. The main outcome measure was writing quality on a posttest without support. The first three studies (Rowley et al., 1998) produced statistically significant effects when analyzed at the level of individual students rather than classes; except for one study in which the control group had no computer access, the effect sizes were extremely small (about 1% of variance accounted for). The fifth study found no significant effect.

Overall, the research on computer programs that provide metacognitive prompts to writers during the writing process has produced more negative than positive results, but there are too few studies to draw any firm conclusions. Zellermayer et al. (1991) was the only study to find improvements in the quality of writing on a transfer essay, but even their study included an unexpected and unexplained negative result for students receiving solicited guidance. Reynolds and Bonk (1996; Bonk & Reynolds, 1992) found increases in revision and writing quality on an essay written with support for college students but no effects on revision or quality for essays written with support or on a transfer essay for middle school students. Rowley et al.'s (1998) studies had design flaws and produced very small effect sizes.

More common in everyday life than prompts with an instructional purpose are tools designed to support planning, such as outliners and concept mapping programs. Despite the popularity among teachers of current concept mapping software, only one study of the effects of concept mapping software on writing was found. Sturm and Rankin-Erickson (2002) compared planning with concept mapping software, hand-drawn concept maps, and no maps in adolescents with learning disabilities writing descriptive essays. Essays were longer and of higher quality in both concept map conditions than in the no-map condition.

A study by Crinon and Legros (2002) adopted a novel approach to supporting revision by novice writers. Arguing that lack of knowledge about good writing is a critical problem for novices, they provided access to a database of model texts to give students ideas about content and solutions to common problems such as how to begin a story. The database was an anthology of 250 excerpts from children's literature, ranging in length from a few lines to a page and half. The texts could be accessed through a search for theme (e.g., friendship, fighting), people and places, or technique (e.g., how to start a story, how to make readers laugh). In the study, 8- to 10-year-old children wrote a first draft in one session and used the database in a second session to help with revision. The database was compared to a paper condition in which children had access to eight story excerpts on the same theme as the assignment and to a no-support condition. The children using computers produced more propositions during rewriting and, in particular, more macrostructural propositions. Most of the additions were inventions rather than direct copies of text. No quality measures were used, and transfer to writing without support was not assessed. Research on using imitation of model essays in writing instruction has shown only modest effects (Hillocks, 1986). However, children writing collaboratively with peers have been shown to adopt techniques used by their peers for later independent writing (Daiute & Dalton, 1993) and modeling is well established as a basic method of learning. Perhaps this database of brief models is more effective than the typical use of models in writing instruction, because it gives writers ideas and helps them with particular problems during writing.

A new direction in computer support for writing development is the use of automated essay scoring (AES) systems to provide feedback to students on their writing in iterative cycles of revision and evaluation. Several AES systems have shown good interrater reliability with human raters (see Shermis & Burstein, Chapter 27, this volume). In addition, systems based on latent semantic analy-

sis (LSA) are able to evaluate the semantic content of writing and how well it matches criterion texts (Landauer & Psotka, 2000). Such systems are able to evaluate the content coverage of an essay or the adequacy of a summary of a larger text. A common problem in writing instruction is that teachers do not have adequate time to provide detailed evaluations of large quantities of student writing. AES systems can provide repeated feedback on students' writing as they revise.

Kintsch, Steinhart, Stahl, Matthews, and Lamb (2000) described the development and initial evaluation of Summary Street, a program that provides feedback to students on how well their summary covers the various parts of a text, whether it meets length requirements, and which sentences might be redundant or irrelevant. In initial studies, sixth-grade students wrote better summaries with Summary Street than without support, but only on more difficult topics. Steinhardt (2001) conducted a controlled study in which 50 sixth-grade students wrote summaries using Summary Street or a simpler version that only gave feedback on length. Students spent significantly more time working on their summaries with Summary Street and received significantly higher ratings on content coverage and overall quality. Many issues remain to be investigated, including transfer to writing summaries without support and the effects on reading comprehension.

Overall, research on computer programs that provide metacognitive support, or procedural facilitation, has produced mixed results. Paper-based procedural facilitators have been shown to have effects on planning and revising processes, and the quality of writing in some studies (Bereiter & Scardamalia, 1987; Ferretti & MacArthur, 2001; Graham, MacArthur, & Schwartz, 1995). Thus, it is likely that computer-based versions could also be effective if appropriately designed and targeted on the needs of the students. Further research and development in this area should focus on the specifics of instructional design.

Another important area for research given the frequent use of graphic organizers and outlines in writing instruction is the design of instruction combined with computer versions of outlining and semantic mapping software. Crinon and Legros's (2002) concept of using a database of model texts to support writing instruction is a novel approach that deserves more research. Finally, applications of AES to writing instruction appear quite promising as ways to improve writing, especially writing in content areas.

Assistive Technology for Struggling Writers

Word processing, as noted earlier, appears to be especially helpful for writers with learning disabilities (LD) and other struggling writers, perhaps because they are in most need of the support it provides for motivation, mechanics, appearance, and revision. In addition to word processing, other computer tools, including spelling checkers, speech synthesis, word prediction, and speech recognition, can offer assistance to writers who struggle with transcription.

Spelling Checkers

Spelling checkers, as one might expect, do help students with LD to correct errors, but with significant limitations. In one study (MacArthur, Graham, Haynes, & De La Paz, 1996), middle school students with moderate to severe spelling problems corrected 37% of their spelling errors with a spelling checker compared to 9% unaided. The most severe limitations were that the spelling checker (1) failed to flag 37% of errors that were other words, including homonyms and other real words (e.g., *sad* for *said*), and (2) failed to include the correct word in the list of suggestions for 25% of errors. High school students with LD can correct more of their spelling errors if taught to use strategies for managing the limitations of spelling checkers (McNaughton, Hughes, & Ofiesh, 1997).

Speech Synthesis

Speech synthesis, or text-to-speech software, has potential as a tool to help students with revision. By listening to the text they have just written, students might be able to use their oral language skills to identify and correct errors they would miss on reading the text. Only one study with elementary and secondary students was found that addressed this potential. Borgh and Dickson (1992) had elementary school students write on a

special word processor that prompted them to check for errors; half of the students used speech synthesis along with the prompts. No differences were found in overall amount of revision or the length and quality of papers.

Word Prediction

Word prediction software was originally developed to reduce keystrokes by individuals with physical disabilities, but it has also been applied with students with severe spelling problems. Word prediction software "predicts" what word the writer intends to type based on the initial letters and, for sophisticated software, syntax and individual patterns of word use. For example, if I have typed, "I went to the *s*," the program might offer a list of predictions including *store, show,* and *same*. If I continue by adding a *t* to the *s*, the program would update the list to include only words beginning with *st*. Most word prediction systems also provide speech synthesis to help students read the list of words.

MacArthur (1998, 1999) conducted a series of three studies of word prediction with 9- and 10-year-old students with severe spelling problems, using single-subject designs that support causal conclusions about the effects of treatment on individual students. Students wrote dialogue journals with their teachers, alternating among handwriting, word processing, and word prediction. Across the three studies, six of eight students demonstrated dramatic improvements in the legibility of their writing and spelling when using word prediction. During baseline, the writing of these six students ranged from 55 to 85% legible words (i.e., readable in isolation) and 42 to 75% correctly spelled words. All six increased their percentage of both legible and correctly spelled words into the 90 to 100% range. A more recent study (Handley-More, Deitz, Billingsley, & Coggins, 2003) with similar students (LD, age 10–11, severe spelling problems) and a similar research design found similar effects; two of three students made substantial improvements in legibility and spelling.

Thus, the available research supports the use of word prediction software with students with severe spelling problems. The studies also revealed that design issues, such as the size of the vocabulary, its match to the writing task, and complexity of the interface, make a difference in the impact. Further research is needed to replicate and extend the findings to other groups and to investigate the impact on vocabulary use.

Speech Recognition

Speech recognition software for dictation represents potentially the most complete solution to problems with spelling, handwriting, and overall fluency. However, despite steady improvements in the quality of speech recognition software, it still has significant limitations in comparison to dictation to a human (MacArthur & Cavalier, 2004). First, accuracy is still limited. Second, users must articulate carefully, dictate punctuation, and avoid extraneous vocalizations. Finally, users must learn to edit for new types of errors. On the other hand, one advantage of speech recognition over standard dictation to a secretary is that writers can see their text as they dictate.

Reece and Cummings (1996) studied the potential effects of speech recognition in a series of studies using a simulated speech recognition system with a hidden typist and visible computer screen. Two studies of fifth- and sixth-grade students, one with normally achieving students and another with students with writing problems, compared papers written via handwriting, normal dictation (to a tape recorder), and simulated speech recognition. For normally achieving students, handwritten and normally dictated papers were equivalent in quality, whereas poor writers did better with normal dictation than with handwriting. Both groups wrote better quality papers with the simulated speech recognition system than with either normal dictation or handwriting. However, in another study, in which normally achieving students were required to develop a plan before writing, the advantage of simulated speech recognition over normal dictation disappeared. The authors interpreted this finding to mean that planning made it less necessary to see the developing text. For students with writing problems, however, dictation in both forms was consistently better than handwriting.

Several studies of speech recognition with struggling writers have been reported. Though focused on college students with

LDs, Higgins and Raskind's study (1995) deserves mention as the earliest experimental comparison of speech recognition, dictation to a human transcriber, and unassisted composing (word processor or handwriting at students' choice). Quality ratings were significantly higher in the speech recognition than in the unassisted condition. Quinlan (2004) selected middle school students who had significantly lower written language than oral language scores (similar to a definition of LD) and compared them to students without such a discrepancy. All students learned to use speech recognition and then composed brief narratives using handwriting and speech recognition. Students with writing problems, but not the average writers, wrote longer papers using speech recognition. However, no statistically significant differences in quality were found by condition for either the poor or average writers.

MacArthur and Cavalier (2004) compared the effects of speech recognition, dictation to a person who typed on a visible screen, and handwriting on the writing of high school students with and without LD. All students received 6 hours of training and practice in the use of both speech recognition and a simple planning procedure for writing persuasive essays, then wrote essays in all three conditions. All students were able to use speech recognition to compose and edit essays. The students with LDs made fewer total errors with speech recognition than handwriting, and few words were unreadable. Their essays dictated using speech recognition were higher in quality than handwritten essays (ES = 0.42), and essays dictated to a person were even better (ES = 1.31). No statistically significant differences for condition were found for students without LDs.

Although the research on assistive technology is not extensive, it provides support for the use of some forms of technology to help students with LDs and other struggling writers compensate for problems with basic transcription. Word processing and spell checkers are clearly helpful and are readily available. Word prediction is promising for students with severe spelling problems. Speech recognition now has solid, if limited, support. One cautionary note is that all assistive technology tools, while removing one burden, impose some new burden. Word processing removes problems with handwriting, but students must learn to type. Speech recognition removes concerns with handwriting, typing, and spelling, but students must articulate carefully and edit for errors. Whether a new tool increases or decreases the overall burden of writing depends on the capabilities of the individual student, the training provided, and the demands of the setting. Thus, further research should investigate which students are most likely to benefit from particular tools.

Hypermedia

We turn our attention now from computer tools that support and instruct writers to technology that changes the nature of the written product. There is a rich literature on the design of hypermedia to enhance the content learning of users (for a review, see Dillon & Gabbard, 1998). In this chapter, discussion is limited to research on the cognitive processes involved in composing hypermedia, or hypertext, and the learning consequences of such composing. The term "hypermedia" is used for studies that involve multiple media, including text, connected by a network of links; "hypertext" is used for research focused on linked text with no other media.

Composing hypermedia and linear text differ in some ways and are similar in others. Both are composing processes with communicative purposes and, as such, require considering the audience, setting goals, organizing with attention to content and rhetorical purpose, presenting content clearly, and evaluating and revising. Hypermedia differ from written text in two major ways: the linked structure and the inclusion of multiple media. These two differences potentially affect all aspects of composing. For example, the multiple purposes of audiences need to be considered in planning the organizational structure of hypermedia (Bromme & Stahl, 2002). Multiple links among segments of content, as well as navigation through the document as a whole, must be considered. The content of individual segments is affected, because the writer cannot count on the reader's having read previous segments. Careful consideration needs to be given to the use of multiple media. In addition, visual

design issues play an important role in usability.

Investigations of the effects of composing hypermedia have been primarily case studies of instruction in classrooms. Experimental studies of the effects of composing hypermedia are difficult to design because of two considerations. First, media comparison studies, like those comparing handwriting and word processing, make no sense because of the lack of comparability of hypermedia and text documents. Second, experimental comparisons of content learning as an outcome of composing hypermedia are confounded by the amount of effort and time devoted to creating hypermedia, not to mention motivational factors. However, a number of case studies have investigated the cognitive and social processes involved in composing hypermedia and changes in students' understanding of the composing, or design, process. In addition, a few recent experimental studies have investigated cognitive processes.

Lehrer, Erickson, and their colleagues (Carver, Lehrer, Connell, & Erickson, 1992; Erickson & Lehrer, 1998, 2000) have conducted a number of classroom studies of collaborative inquiry projects based on authoring hypermedia. In their studies, students worked collaboratively to investigate topics within a classroom unit of instruction and made hypermedia presentations to teach their peers what they learned. Students received instruction in the hypermedia authoring tools, and explicit instruction and guidance in the design process. The researchers developed a theoretical model of the design skills, or cognitive processes, required for hypermedia composition and argued that those design skills were important educational outcomes. The model described a wide range of cognitive skills covering research skills, planning and management, organization, presentation, evaluation, and revision. They then used the model to design the curriculum, to document exposure to instruction in design skills, and to assess students' conceptual understanding of the design skills, their use of design skills in class projects, and their transfer of skills to novel tasks. Carver and colleagues (1992) reported case studies of a ninth-grade class that worked directly with the researchers, and a group of three eighth-grade classes taught by their teachers. Both groups participated in 10-week units and 4-week follow-up projects to assess transfer. Analysis of student discourse, self-report measures, and design performance on the transfer tasks demonstrated gains in design skills in both sites. However, students taught by their regular teachers received less explicit instruction in the design process and developed less independence in design, especially regarding the overall research process.

Erickson and Lehrer (1998) conducted a 2-year longitudinal study with a group of sixth- and seventh-grade students who participated in a series of hypermedia inquiry projects in social studies. They documented changes in students' understanding of what constituted good research questions and what characterized good hypermedia design. Understanding of research questions evolved from simple factual questions to thought-provoking questions that required interpretation. Standards for hypermedia design evolved from a focus on display features and content information to a greater focus on clarity of communication and consideration of audience. For example, students devoted more attention to multiple representations of content, and the purpose and organization of links. The analysis also revealed the extent to which student development of design knowledge depended on explicit instruction, based on assessment of student understanding.

Erickson and Lehrer (2000) conducted a more detailed analysis of students' developing understanding of links and the hypermedia space. They based their analysis on Bereiter and Scardamalia's (1987) theory that knowledge-transforming writing results from an interaction between the content-problem space and the rhetorical-problem space, as writers revise and extend their understanding of content by wrestling with the necessity of communicating ideas clearly to readers. Detailed analysis of the development of 10 students over the course of a year showed a change from an exclusive emphasis on content links to a greater rhetorical emphasis on facilitating navigation and organizing content for readers by using links that indicated specific relationships among content.

Liu (1998) and colleagues (Liu & Hsiao, 2002; Liu & Pedersen, 1998) conducted a series of studies with high school, middle

school, and elementary school students working on multimedia design projects. Though they used a rationale similar to that of Erickson and Lehrer (1998, 2000), and used a variation of their design questionnaire to measure gains in design knowledge, their projects differed in that they focused on the design of hypermedia as done by professional designers, with an emphasis on presentation rather than on the inquiry process of research and communication. This narrower emphasis on designing presentations limits the application of Erickson and Lehrers' argument for the relevance and importance of design skills. In addition, the studies were primarily pretest–posttest designs with single classes, with limited analysis of qualitative data. Results on the quantitative measures were mixed. They found increases in motivation and design knowledge in the high school class but mixed results in the middle school and elementary school studies. Qualitative analysis of interviews and observations showed that students were engaged and developed knowledge of design, but their claims should be interpreted cautiously.

Other case studies of educational projects with hypermedia have taken different approaches. Myers, Hammett, and McKillop (1998) discussed the use of hypermedia to support critical pedagogy. In their case studies, high school students used hypermedia to construct critical commentaries on literature. By linking images and commentary to texts, they created juxtapositions that involved reinterpreting the texts, questioning the underlying assumptions, and reflecting on culture and ideology. Although Myers and her colleagues believed that hypermedia afforded the opportunity to critique texts, they acknowledged that the effects of the technology were dependent on the ways in which teachers and students used them.

Daiute and Morse (1994) reported a case study of a class of reluctant writers who produced simple multimedia documents based on pictures or sounds that they brought to school because they had personal meaning. They compared such multimedia writing to the drawing in which primary students are commonly engaged. The case studies of individual students revealed high levels of engagement and increased production of text.

Baker (2001; Baker & Kinzer, 1998; Baker, Rozendal, & Whitenack, 2000) reported a series of analyses of an ethnographic case study of a fourth-grade class in an intensive technology environment with a 1:1 ratio of computers to students plus five multimedia stations. Students worked on collaborative inquiry projects in science and social studies that often involved hypermedia presentations and engaged in a variety of writing activities during language arts time. In this setting, the composing process was highly recursive, with students brainstorming, searching for information, composing, and revising repeatedly in various orders (Baker & Kinzer, 1998). Often students revised hypermedia products they had completed and presented much earlier. One apparent reason for this recursive activity was the public nature of composing on the computer screen (Baker et al., 2000). Students were often observed to comment on each other's work or to stop and talk as they walked by a peer's computer. The classroom offered pervasive opportunities for interacting with a peer audience through presentations, solicited and unsolicited feedback, and frequent viewing of others' screens, often without comment. The teacher saw not only positive value in this public nature of writing, in that students got ideas from each other and received lots of support in revising, but also potentially negative implications in the lack of opportunity to write privately in journals. Another issue about the impact of technology was the effects of publication and presentation. Students in this class were highly motivated by the presentational tools at their disposal. However, the teacher expressed some concern about an overemphasis on presentation to the detriment of substance. A common theme of her conferences with students was encouraging them to find more content for their reports.

One experimental study with high school students investigated the cognitive processes involved in composing hypermedia. Braaksma, Rijlaarsdam, Couzijn, and van den Bergh (2002) compared the cognitive processes involved in composing hypertext to the processes involved in composing standard linear text. They used artificial tasks designed to represent the key processes of hierarchicalization for hypertext and linearization for standard text. The hypertext task required students to take a paragraph-length argu-

ment and draw a diagram of the thesis, arguments, and subordinate arguments. The linearization task required students to take such a hierarchical diagram and write a short argumentative paragraph. Think-aloud data were gathered, and the quality of products was assessed. Each student did two tasks of each type, one easier and the other harder. The overall quantity of think-aloud statements was greater in the hypertext task. In terms of proportions, the hypertext task elicited more analysis, planning, goal setting, and meta-analysis, while the linear task led to more writing and rereading statements. For both tasks, the amounts of planning and analysis were positively correlated with the quality of products. The authors interpreted the results as evidence of considerable similarity in the general types of cognitive processes involved in composing text and hypertext, and suggested that composing hypertext may have a positive effect on linear writing skills by promoting more planning and analysis.

In summary, research on the effects of composing hypermedia is at an early stage. The case studies have demonstrated the potential of instructional models that combine technology and collaborative inquiry, and have analyzed some of the cognitive processes and instructional factors involved. They have avoided unproductive media comparisons. After all, research on models of collaborative inquiry without the use of technology, such as Group Investigation (Shachar & Sharan, 1994), has shown positive effects on student content learning and learning of inquiry processes. Instead of asking about the effects of technology, these case studies have investigated how to use hypermedia effectively. The studies have illuminated some of the cognitive processes involved in using hypermedia, such as an understanding of how to divide content into segments and link them in ways that are responsive to readers' needs, or how to use multiple media to communicate effectively rather than simply to make a flashy presentation. They have also pointed to important social considerations, such as the impact of the public nature of technology on interaction with peers. Finally, they have drawn important conclusions about the importance of instruction guided by a model of the cognitive processes and learning outcomes desired.

Experimental study of particular aspects of hypertext composing has just begun. The case studies and experimental studies together show that composing hypermedia requires high-level cognitive processes and can help to develop those processes. Though perhaps somewhat different in emphasis, the cognitive processes seem similar to those required for writing, involving setting goals, considering audience needs, generating and organizing content, evaluating, and revising. Continued research is needed to understand these cognitive processes in more detail and to develop effective classroom environments that include hypermedia composing.

Computer-Mediated Communication

The term "computer-mediated communication" (CMC) covers a diverse range of technologies and contexts for use, unified only by the idea of interactive communication over the Internet or local networks, primarily via writing, though sometimes supplemented with other media. It includes everyday professional and personal use of e-mail, listservs, instant messaging, and chat rooms, as well as specific instructional and professional uses, such as online and distance courses, online discussions in traditional courses, and collaborative work groups and meetings. The large body of writing on CMC is primarily practical and descriptive but also includes theoretical and empirical work. Social-psychological research has examined interaction patterns in CMC (see a review from the point of view of composition by Eldred & Hawisher, 1995). The use of synchronous and asynchronous CMC in online courses or distance education has generated a body of examples and principles for practice (see the multiple-volume edited set by Berge & Collins, 1998). Linguists have conducted descriptive research on the syntax, semantics, and pragmatics of communication via email and instant messaging (e.g., Baron, 1998). CMC has been widely used in college writing courses (for a historical review, see Palmquist, 2003; for research on one extensive project, see Bruce, Peyton, & Batson, 1993).

Because CMC is communication conducted via writing, all of this work is relevant to some degree to this chapter. How-

ever, this chapter is confined to a review of studies that looked specifically at the effects of CMC on writing processes and writing products in the context of writing instruction. At the elementary and secondary school level, this research has focused on telecommunication projects, often involving classrooms from different cultures or geographical areas.

Intercultural communication projects using the Internet have been proposed as ways to improve students' writing skills, develop greater cultural awareness, and prepare students for an increasingly globally connected world (Garner & Gillingham, 1996; Fabos & Young, 1999). The scope of projects varies from simple pen pal communications to collaborative curriculum projects that involve sharing of data and written products. Such projects offer substantial opportunities to communicate in writing for authentic purposes with age peers from culturally different backgrounds. Communication with distant peers may cause students to think more carefully about audience, and to be more explicit and elaborative in their writing. The authenticity of the writing and the technology may also motivate students to write more. However, little empirical research has tested these possibilities.

Cohen and Riel (1989) had two classes of seventh-grade students in a repeated measures design write papers on the same topic for the teacher for a grade and for a distant audience of peers. These students had no prior experience with email or writing for distant peers. The papers written for the distant audience were rated higher on all five aspects of an analytic scale and given higher grades by the teacher. Gallini and Helman (1995) collected writing samples from fifth-grade students who had experience in an intercultural communication project. Students were randomly assigned to write papers for their teacher, for a self-selected classmate, or for distant peers. The papers written for distant peers were rated significantly higher than others on several elements of an analytic scale—organization, elaboration, and interest. These studies provide preliminary support for the value of writing to distant audiences, but both studies were small and involved a single writing sample.

Case studies of intercultural communication projects have also been reported. Based on a series of six case studies of innovative teachers using the Internet, Garner and Gillingham (1996) argued that intercultural communication projects encourage more social-constructivist methods by supporting collaboration and student inquiry. The teachers in these cases changed their teaching by devoting more effort to inquiry methods that drew on student interests and real-world concerns. The researchers found high levels of motivation for writing, substantial amounts of writing, and evidence of children attempting to understand cultural differences and to consider audience needs. Case studies have also revealed some of the institutional and social complexities of establishing Internet communication projects. For example, Neilson (1998) discussed a large telecommunications project in a rural high school. A variety of institutional barriers and difficulties in managing projects resulted in an implementation that reached only a few students who were especially interested in technology.

Fabos and Young (1999) wrote a highly critical review of telecommunications projects, pointing out the lack of empirical research on outcomes, and urging educators to look critically at the political and social forces that support such global communication projects. Case studies have demonstrated the potential of intercultural communication projects, but given the popularity of such projects, much more research is needed to document their effects on writing and other types of learning, and to gain understanding of the factors required for successful projects.

Concluding Comments

In considering research on technology and writing, it is helpful to divide it into two parts: research on the use of technology to support traditional writing outcomes, and research on new forms and contexts for writing. Research on traditional outcomes has asked whether writing processes or the quality and quantity of written products are affected by the use of word processing or programs that support writing by providing metacognitive prompts, organizational support, automated evaluative feedback, or support with transcription. The answer, it turns

out, is, "It depends." Word processing by itself has minimal impact on written products, but in combination with instruction, it can help students develop better writing skills. Research on software that provides metacognitive prompts or procedural facilitators has produced mixed results, which suggests that the key issue is instructional design. Research on promising areas, such as the use of automated evaluation systems to provide feedback, is just beginning, but it seems likely that the design of the feedback and the surrounding instruction will be critical. Assistive technology has been shown to be effective under certain conditions, but it has important limitations that make the effects dependent on the match of student and tool, as well as instructional support. Computers are powerful, flexible tools for writing and writing instruction, but their effects depend on the design of the software and ways that instruction takes advantage of computer capabilities.

Questions about the educational impact of new forms of writing, such as hypermedia, and new social contexts for writing, such as CMC, have been more difficult to define and to answer, and the research is quite limited. A few studies of intercultural communication have asked questions about the effect on traditional written products. A more common approach has been to use qualitative methods to describe the social and cognitive processes that occur in classrooms using hypermedia or CMC. Research on CMC at the elementary and secondary level is limited primarily to case studies of intercultural communication. Case studies of classrooms using hypermedia have provided evidence about some of the cognitive processes required for creating hypermedia, as well as the impact on social interactions. They have also pointed out the importance of instruction guided by a model of the cognitive processes and learning outcomes desired.

It is possible that most of technology's impact on writing will come, not through direct use of technology in school, but rather through the changed experiences of students outside of school and new requirements for skills needed after school. In addition to more research on the educational interventions discussed in this review, research is needed on the impact of these larger societal factors.

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