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3

Bringing Insights from Reading Research to Research on Electronic Learning Environments

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INTRODUCTION

Since Rumelhart (1976) first proposed an interactive model of text processing, it has become nearly axiomatic in the reading community to describe reading as an interactive process (e.g., Hittleman, 1988; Kim & Goetz, 1994; May, 1986). Rumelhart's model portrayed the nature of reading comprehension as an internal interaction *within* the mind of the reader; multiple, parallel processing, knowledge sources simultaneously interacted with one another, sharing information about a text until one interpretation was determined to best represent meaning. Since this early work by Rumelhart, however, the internal interaction that takes place during reading gradually has come to be redefined as an external interaction. Today, the concept of reading as an interactive process frequently is used to described what takes place *between* a reader and a text; readers are thought to interact with a text as they construct meaning and achieve comprehension (Tierney & Pearson, 1983; Tierney & Shanahan, 1991). Current interpretations of reading as an interactive process often give the impression that both text and reader contribute equally to a dynamic, interactive relationship.

Unfortunately, viewing reading as an interaction between reader and text is an idealized and somewhat metaphorical interpretation of this process. As Reinking (1992) has pointed out, the notion that readers and texts interact is not completely accurate since an interaction implies that at least two elements actively engage one another. During reading, readers are the only active participants; traditional texts, of course, remain static.

Electronic learning environments, however, provide an opportunity to operationalize this idealized notion of a dynamic, reciprocal interaction between readers and texts. We use the term "electronic learning environments" to refer to environments where text carries at least a portion of the information within an interactive electronic medium. Electronic learning environments include what are commonly referred to as hypertext (Bolter, 1991), hypermedia (Marchionni, 1988), or multimedia (Schank, 1994). Within electronic learning environments, readers actively manipulate the nature of the information they encounter as they navigate through flexibly structured resources in an attempt to construct meaning. Recent examples of what we refer to as electronic learning environments include many locations on the World Wide Web and the increasing number of CD-ROM programs used at school and at home to promote learning.

Many electronic learning environments actively respond to readers who seek information from multiple media sources. Hillinger (1992), noting this interactive potential, refers to electronic learning environments as "responsive text" since they can respond to the unique needs of a reader seeking to construct meaning. An electronic learning environment, for example, might pronounce a word for a young student struggling with decoding, provide an explanation for a difficult concept unfamiliar to a user, animate a complex process to illustrate causes and consequences, provide a video segment to demonstrate a procedural routine, or display written responses by other users about their learning experiences. Consistent with Rumelhart's early model, comprehending printed material in electronic learning environments involves an internal interaction *within* the mind of the reader as different knowledge sources share information about the meaning that is constructed. However, comprehending printed material in electronic learning environments also brings into play a dynamic, external interaction *between* a reader who may seek additional information and an electronic learning environment responding to these requests. As a result, the previously metaphorical interactions between readers and texts now become real.

Although the potential of electronic learning environments for assisting students has been discussed often (e.g., Balathy, 1990; Blanchard, 1990; Van Dyke Parunak, 1991b), virtually every leading scholar in this area has bemoaned the limited empirical research and theory that could produce better understanding of these environments; there is far more intuitive speculation in this area than there is systematic research and theory development (Alexander, Kulikowich & Jetton, 1994; Spiro & Jehng, 1990). As a result, the design of electronic learning environments is nearly always based on intuition and hunch rather than data and theory. It is likely this weakness has limited the ability of current designs to support students' learning.

Recently, intriguing theoretical perspectives about learning in these dynamic environments have begun to emerge (Bolter, 1991; Scardamalia & Bereiter, 1991; Spiro, Feltovich, Jacobson, & Coulson, 1992). These will be helpful in creating more focused, theoretically driven research agendas. Although these focused perspectives are useful, we believe it is also important to draw from lines of research in diverse disciplines, including reading, in order to develop questions that can contribute to broader theoretical frameworks that might be missed with a narrower view.

It is ironic that we suggest that work in reading research might be useful to identify promising research issues within electronic learning environments whereas, at the same time, we argue that the central construct in much of this research, the dynamic interaction between reader and text, is often misinterpreted. Yet, this is exactly what we propose. We assume that electronic learning environments, where interactions between readers and texts occur literally, will make many insights about interactions discovered from reading research even more salient. We recognize, however, that the utility of these insights will be modified by several factors, such as the differences between internal and external interactive processes, the more numerous symbol systems available to an electronic medium using multiple media to convey information, the important differences between reading comprehension and learning, and the different attributions individuals assign to traditional texts and electronic learning environments. Nevertheless, we believe that insights from reading research may provide a useful initial agenda for pursuing research on learning within the much more dynamic, responsive, and truly interactive electronic environments that are now possible.

The purpose of this chapter is to discuss how several insights from reading research, central to understanding the more limited interactions between readers and texts, can apply to electronic learning environments. We believe each may be useful to inform our understanding of the more powerful interactions that take place within responsive, electronic learning environments. Six insights from reading research are especially important to consider.

1. It is more important to study interactive processes than products;
2. In order to understand interactive processes, one must understand the role of prior knowledge.
3. In order to understand interactive processes, one must understand the role of strategic knowledge.
4. In order to understand interactive processes, one must understand the role of interest and other motivational factors.
5. Interactive processing is supported when reading and writing are connected.
6. Research and software design are both enhanced when they are grounded in classroom contexts.

We believe studying each of these areas within electronic learning environments will inform the development of broader, theoretical frameworks to guide further research. At the same time, the data gathered from exploring these areas should provide useful insights into software design that maximally supports students' learning. In fact, we will argue that more consistent and profound outcomes in electronic learning environments have yet to be realized because important insights in each of these areas have yet to be considered in the design of current software.

As we discuss each issue, we will review related work occurring in both reading research and research on electronic learning environments. Throughout the discussion, we hope it will become clear how our backgrounds in reading research have guided our explorations into this area. Although some might argue this limits our perspective on these fundamental issues, we believe our backgrounds provide a special lens with which to look at electronic learning environments. As scholars from other fields also contribute their own special perspectives to these issues, our understanding of learning within electronic environments will benefit. Ultimately, it is essential that scholars from diverse fields join together to understand and exploit fully these new contexts so that teaching and learning are improved. We hope to contribute to this dialogue.

IT IS MORE IMPORTANT TO STUDY INTERACTIVE PROCESSES THAN PRODUCTS

A central aspect of studying interactions in reading research has been to concentrate on the process rather than the product. *Product outcomes generally have been useful only as they inform us about the nature of the reading process.* Given our backgrounds in this area, it appears fundamental to us that research on electronic learning environments begins to focus on interactive processes as much as on the products of learning. By looking carefully at the interactions between students and electronic learning environments we will be able to develop better explanations for how outcomes are achieved in these environments, something that is fundamental for both theory development and the design of more supportive learning environments.

Research on reading during the 1970s and early 1980s focused on reading processes, largely from a cognitive perspective. Research into the reading process established the central psychological reality for many important cognitive constructs that continue to influence theory and practice today. Schema-theoretic research, for example, explored the nature of our mental representations for concepts (Anderson & Pearson, 1984) and procedural scripts (Schank & Abelson, 1977) as well as the construction of mental models (Collins, Brown, & Larkin, 1980) and situation models (van Dijk & Kintsch, 1983). Miscue research was a direct outgrowth of linguistic and cognitive theory and provided insights into the expectations readers generated during reading (Leu, 1982). In addition, research into the nature and role of discourse knowledge contributed important insights into the consequences of text structure for comprehension (Armbruster, 1984; Meyer, 1975). Finally, important work on inferential processes allowed us to understand the active contributions readers make to the meaning they assign to text (Trabasso, 1981). When combined with other work, such as the development of automaticity theory (Samuels & Eisenberg, 1981), these early lines of research provided us with powerful insights about the nature of the reading process. In an important way, they also have informed more recent, socially grounded research into the nature of reading development that also tends to focus on process issues (Newman, Griffin, & Cole, 1989).

The emphasis on process issues in reading stands in dramatic contrast to what we find in the research on electronic learning environments, where the emphasis often appears to be on learning outcomes. It is clear to us that outcome-based research is important to demonstrate the ability of electronic learning environments to assist learning, especially given the limited nature of compelling and consistent research results on this issue (e.g., McGrath, 1992; Schare, Dunn, Clark, Soled, & Gilman, 1991; van der Berg & Watt, 1991). Clearly, a stronger case needs to be made for the efficacy of electronic learning environments. However, one of the reasons more consistent results have not been obtained is that the design of these studies has not yet been informed by systematic research about the processes associated with interactive learning environments. Process research would do much to help us understand optimal support structures for learning. For example, which types of dynamic, information support do students gravitate toward as they attempt to create meaning within electronic learning environments? Which informational support structures yield increases in learning? Do students with different levels of prior knowledge benefit from different types of informational support structures? When text is present, do students with different levels of reading achievement benefit from different types of information? Which types of media sources best support certain types of learning? Answers to these and other process questions will inform the development of more supportive electronic learning environments and lead to more consistent and compelling data on their efficacy.

Although some studies have explored process issues in relation to static physical features such as screen size or text layout (e.g., De Bruijn, de Mul, & Van Oostendorp, 1992; Dillon, 1994), we find relatively little work on interactions with dynamic features such as those described in the preceding paragraph. This gap is surprising given the importance of defining more supportive electronic learning environments. It is also surprising given the ease with which these data may be obtained with the aid of a computer. Research on internal reading processes always has been limited by the lack of observable process data. With the exception of miscue research, which looks at observable oral reading errors, process research in reading requires manipulating different contexts in order to obtain indirectly patterns that are not readily visible. In studying electronic learning environments, however, it is relatively easy to determine much of the on-line processing by directly observing the overt interactions students have with the learning environment. Providing learners with carefully selected choices in an electronic learning environment and then recording their choices provides unobtrusive opportunities to monitor covert processes.

Some of the work we have conducted in electronic learning environments has been guided by a concern for process issues, often in combination with learning outcomes. For example, one of us (Reinking, Pickle, & Tao, in press), explored the effects of inserted questions on the reading comprehension process of college students. Readers were required to review relevant portions of a text when a question was answered incorrectly. When readers failed to answer an inserted question correctly, they spent more time reviewing the paragraphs necessary to answer inserted questions, but only if they knew that they would receive the same question following review as opposed to a different question. In addition, when students knew that a different question would follow their review of each paragraph they performed better on inferential questions than literal questions on a post-reading test. Studies such as this can provide useful information about the nature of comprehension processing within electronic learning environments and the types of supportive structures that are useful to students. Such studies also provide information about how information can be presented electronically to effect changes in students' learning and study strategies. By analyzing the effects of manipulations in electronic environments we can acquire a more systematic picture of learning processes. Such information is crucial to designing more supportive electronic learning environments for students.

One of us (Leu, Gallo, & Hillinger, 1995) has taken a slightly different approach to understanding process issues by observing patterns of on-screen choices made by students. In this study, a chapter from a sixth-grade social studies textbook was converted into a hypermedia environment in order to evaluate interaction patterns by students who varied in reading achievement level. The study also compared comprehension in the two different information environments. Results indicated higher levels of recall among students in the hypermedia condition when compared to the traditional textbook version of the passage. Most important, though, process data indicated that students differentially exploited supportive features depending on their reading achievement level. Low achieving readers more frequently used a "close-up" feature. The "close-up" feature assisted with acquiring central ideas by providing additional graphical information and interactive animations. Average and high ability readers more frequently used a "check-up" feature. The "check-up" feature allowed students to monitor comprehension by interacting with graphical elements to evaluate their understanding of text segments. In essence, weaker readers attempted to construct meaning, whereas better readers attempted to evaluate the meaning they had constructed. These different patterns of processing by reading achievement level suggest that electronic learning environments need to account systematically for the learning needs and strategies of different types of students. It seems clear from this work that research should explore additional differences between subjects that may influence the ways in which they exploit information presented in electronic learning environments.

An increasingly important issue, for example, concerns the populations that have been used as subjects in studies of electronic learning environments. As Alexander, Kulikowich, and Jetton (1994) point out, these studies most often use high school or college students. When younger subjects are used, it is often to study writing processes (e.g., Turner & Dipinto, 1992) or to foster cooperative learning strategies (e.g., Signer, 1992). If this pattern continues, we run the risk of developing theoretical frameworks that ignore developmental differences in how students interact with electronic learning environments, specifically the types of information they find most useful to learning. In addition, we may erroneously propose software solutions for younger students based on data from older students, who process information differently.

There are other ways, of course, to generate process data during learning with electronic environments. Work by Scardamalia and Bereiter (1991), for example, takes a somewhat different approach but provides us with important insights about the use of student-generated questions to guide students in building knowledge structures. Other work by Spiro and his colleagues is beginning to test cognitive flexibility theory that deals with learning content in ill-structured domains of knowledge, such as medial diagnoses. Jacobson and Spiro (1993), for example, found greater transfer of knowledge within a complex knowledge domain when college students read information in hypertext. On the other hand, students receiving information in a more conventional environment performed higher on measures of factual knowledge.

All of this work is important to developing greater insight into students' actual learning processes as they interact with electronic learning environments. We believe process issues such as these will become even more important to define optimal designs of computer interfaces as electronic learning environments rapidly include additional interactive, nonprint based information (video, speech, animations, simulations, and graphics). We also believe that careful observation of student interaction patterns is essential if we are to develop greater insight into the nature of these processes. Finally, we believe it is essential to begin exploring these issues in relation to differences in a wide variety of subject characteristics. It is only after accomplishing these goals that we will be able to develop more useful and comprehensive theoretical perspectives and more supportive structures for learning.

UNDERSTANDING THE ROLE OF PRIOR KNOWLEDGE DURING INTERACTIVE PROCESSES

Prior knowledge has been explored extensively as a variable accounting for the comprehension of traditional texts. Prior knowledge has a powerful effect on both the quantity and quality of learning that takes place during reading, producing robust effects that include: increasing interest and recall of information (Alexander, Kulikowich, & Jetton, 1994), increasing the types and quality of self-generated questions (Scardamalia & Bereiter, 1991), and determining the interpretation of ambiguous passages (Bransford & Johnson, 1973). Also, it is clear that the effects of prior knowledge increase as students move through the educational system (Alexander, Kulikowich, & Jetton, 1994) and as the informational density of a passage increases (Tyler & Voss, 1982); prior knowledge effects are most pronounced among older students and when information density is greatest.

Electronic learning environments provide two characteristics that may be especially useful in helping learners overcome a lack of prior knowledge in complex and informationally dense texts: the ability to respond to students' information needs based on their unique differences in prior knowledge and the ability to present information through multiple media. By responding to students' information needs, electronic learning environments achieve a dynamic and responsive quality not possible in static texts and may be able to compensate for the effects of differences in prior knowledge. This potential increases when information can be presented in a variety of different media; students unable to acquire the information through one medium may be able to acquire it through alternative media. Thus, it is important to understand the extent to which electronic learning environments can assist individuals who have little prior knowledge about a topic.

Hillinger and Leu (1994) recently evaluated the ability of a hypermedia environment to overcome limitations of prior knowledge about a complex and informationally dense topic. They created a hypermedia version of a training manual for the repair and maintenance of a CT7-9 turboprop engine and evaluated learning among high and low prior knowledge subjects. High prior knowledge subjects were members of an air force propulsion unit responsible for the repair of F-16 jet fighter planes and familiar with high performance engine systems. Low prior knowledge subjects were university students unfamiliar with high performance engine systems. In this study, the low prior knowledge subjects achieved the same level of learning with the hypermedia environment as the more knowledgeable service personnel, a finding seldom reported in the literature on the comprehension of conventional printed texts. This finding held for both specific, targeted information defined in the learning task before treatment as well as for general, nontargeted information unrelated to the learning task. It also was sustained when covariate analysis controlled for differences in the amount of education between the two populations.

This study also evaluated interactions between levels of prior knowledge and whether the route through the hypermedia environment was controlled by the system or by the user. In the system-control condition, users proceeded through the hypermedia environment in a linear fashion by following a system-controlled guide. This guide assisted learners in accomplishing a series of objectives central to the learning task that was given to all participants. Figure 3-1 illustrates one screen from the system-control condition, showing the nature of this guide as a participant attempted to accomplish the second objective ("Identify the components of the hot section"). Here, the participant has selected the "do it" button in order to "zoom in" on the core section of the engine, the location where the hot section components can be found. He has also opened the text window as directed by the guide and is reading the information about the core section module. During the third objective, the guide will show the participant how to take apart the core section and find

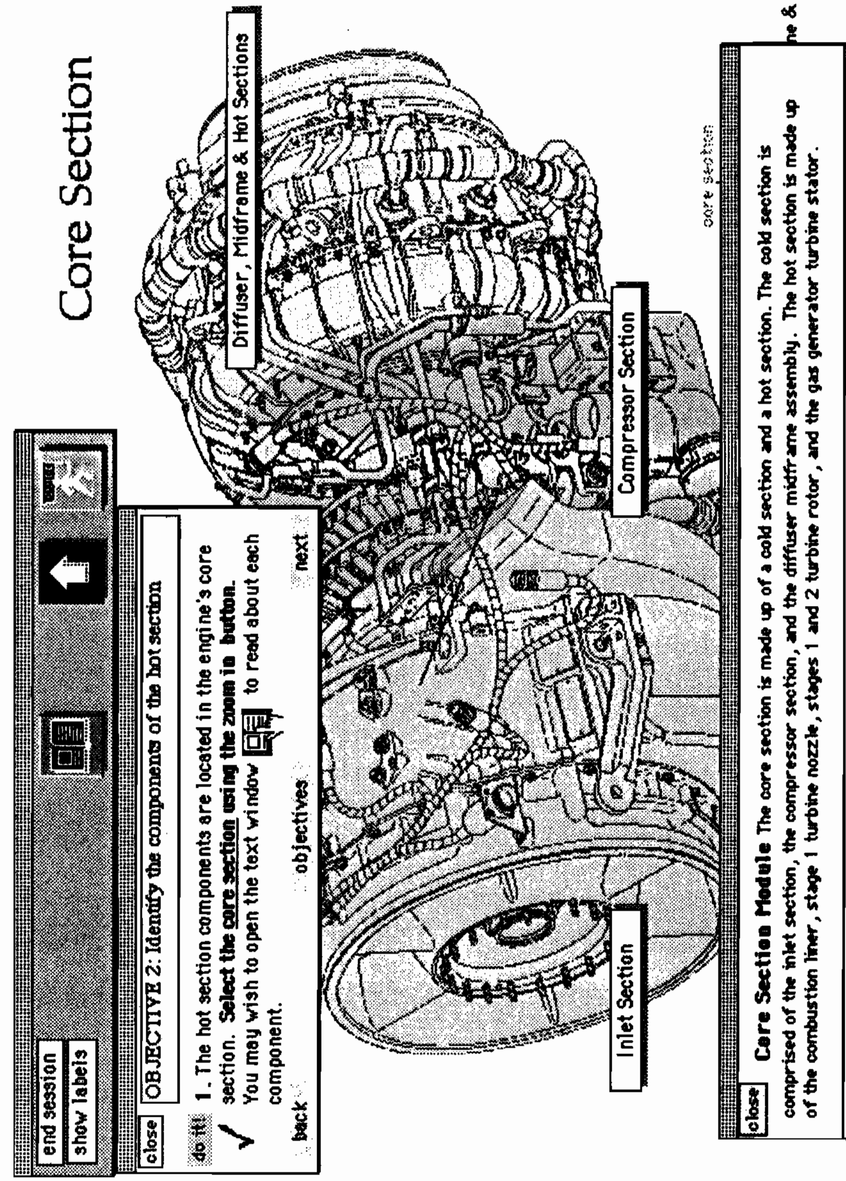

FIGURE 3-1. A view of one screen in the system-control condition showing the nature of the learning guide.

each of the hot section components that lie within. As this is done, video, text, and animations will be available to explain the function of each hot section component.

In the user-control condition, subjects were free to explore the hypermedia environment on their own, looking at any area they wished in any sequence they desired. In both conditions, the same types of support structures were available. By using elements of the tool bar at the top of the screen, subjects could view animations illustrating different aspects of jet propulsion theory, watch videos of each part being assembled and disassembled, take the main sections apart on the screen or put them back together, read text explaining essential information about a part, or move in for a closer view of any part. Figure 3-2 shows one screen from the user control condition, including a text segment explaining the function of the combustion liner (one component of the hot section) and a video segment showing how a combustion liner is removed.

The results of this study indicated an interaction between the type of control and level of prior knowledge. Low prior knowledge subjects, asked to learn specific, targeted information, performed best under system control. Higher prior knowledge subjects, asked to learn specific, targeted information, did best under user control. For learning general, nontargeted information, the nature of the control system did not affect learning outcomes for either group.

This study illustrates some of the special characteristics of electronic learning environments that need to be explored in relation to the role of prior knowledge; system control or user control, for example, is not an issue during the reading of a conventional, printed text. The nature of control only becomes important for the rich and complex information structures that are possible in electronic learning environments. There are other unique insights about learning within electronic environments that also would be revealed by thoughtful explorations into the role of prior knowledge. For example, does prior knowledge assist or interfere with the acquisition of knowledge in ill-structured domains where multiple knowledge representations are possible? One might argue that prior knowledge would allow a more multiple-faceted understanding of meaning. On the other hand, it could be argued that prior knowledge might narrow a reader's interpretation and interfere with learning. Work on this issue from the perspective of cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1992) would be helpful for understanding learning in these unique types of domains.

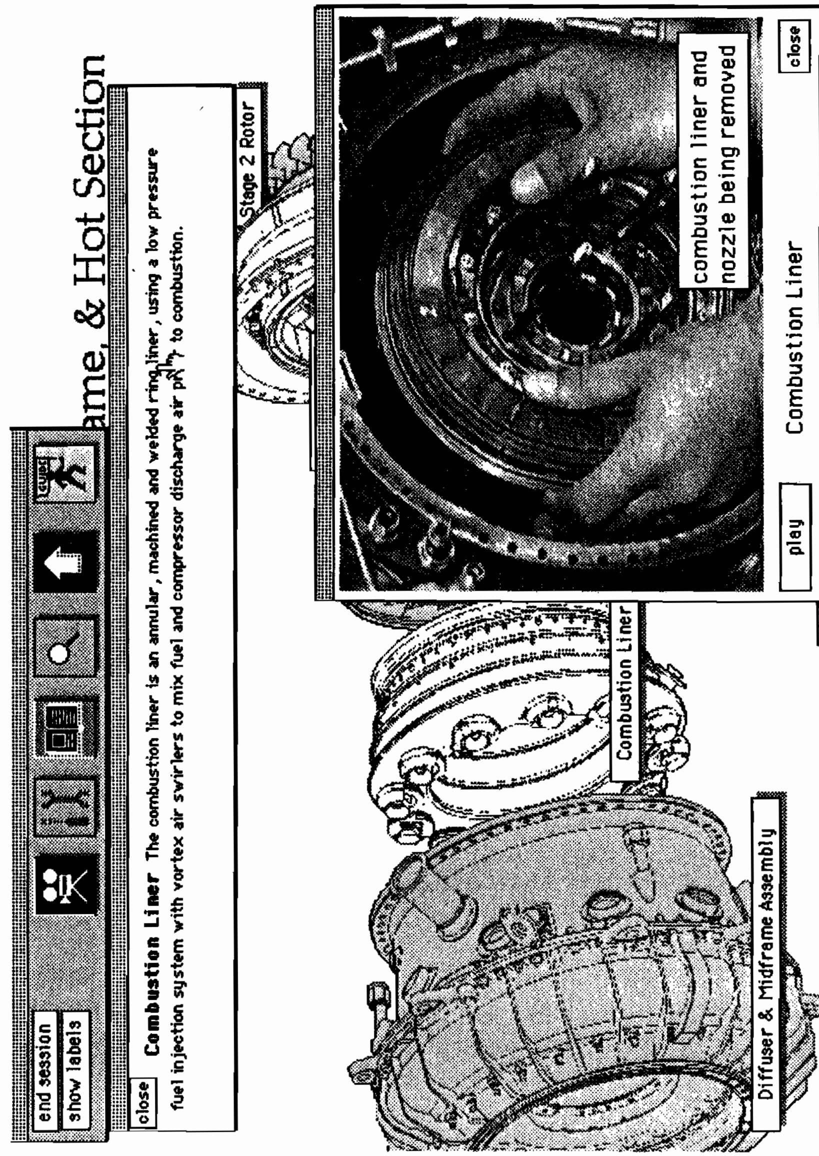

FIGURE 3-2. A view of one screen in the user-control condition showing the nature of different information resources available to the learner.

UNDERSTANDING THE ROLE OF STRATEGIC KNOWLEDGE

Another area central to any understanding of interactions between students and electronic learning environments is the role of strategic knowledge. Work in reading over the past several decades has demonstrated the importance of strategic knowledge to reading comprehension (Brown, 1980; Paris, Wasik, & Turner, 1991). It comes as no surprise, therefore, that studies in electronic learning environments are also focusing on this important issue (Beeman et al., 1987; Bernstein, 1991; Trumbull, Gay, & Mazur, 1992; Van Dyke Parunak, 1991b). It is quickly becoming clear that strategic knowledge may be even more important within electronic learning environments than within traditional, static texts because electronic environments require more decisions about which sources of information to explore in order to accomplish a learning goal.

As we review the literature, we find most work on strategic knowledge in electronic learning environments has focused on what Bernstein (1991) has referred to as the "navigational problem," the difficulties inherent in navigating through interconnected information nodes. Clearly, this macro level focus on strategic knowledge is important given the unique navigational challenges presented by nonlinear information structures. This work will yield important information about the most appropriate types of interfaces to reduce the strategic knowledge demands of users and support learning processes.

There are two other areas related to strategic processing, however, that we believe are equally important to consider in research on electronic learning environments. First, although many studies focus on navigational and interface issues, we can locate no studies that address strategic decisions at the word, sentence, or paragraph levels when learning information presented in a nonlinear structure. Nor can we find studies examining relationships between these micro-level decisions and graphic-, video-, or audio-based information. Strategic processing at microlevels has been more thoroughly explored in reading comprehension studies using traditional, static texts (Brown, 1980; Garner et al., 1991; Jetton et al., 1992; Paris, Wasik, & Turner, 1991). There are many useful insights that might be drawn from these studies. It is important, however, not to assume that micro-level strategic processes are identical in both traditional texts and electronic learning environments. There are, of course, different sources of information in electronic learning environments. Thus, strategic processing may be different when electronic environments contain audio, animated graphics, and video, especially when all of these information sources appear in combination with written prose. Moreover, from the perspective of limited attention models (e.g., Samuels & Eisenberg, 1981), it is likely that conscious decisions about strategic processing at the macro level, an area where there are greater demands within electronic learning environments, may alter strategic processing at the micro level. Given the importance of micro-level strategic processing from studies of reading comprehension and the unique characteristics of electronic learning environments, studies of micro-level strategic processing may yield important insights for both theory development and software design.

Second, given the importance of strategic processing in most electronic learning environments, we are surprised how often this type of knowledge goes uncontrolled in experimental studies. Often it is assumed that all subjects are equally adept at exercising the strategic knowledge demands of software used in the experiment. Infrequently, a short training session and preassessment measure are used to assure that subjects are familiar with the strategic knowledge demands in the study. In these cases, unfortunately, the training and preassessment measures are seldom thoroughly described and are almost never related to theoretical work on strategic processing, which might clearly identify the different types of strategic knowledge required to exploit the information structure. As a result, the majority of studies seldom ensure that subjects are familiar with the strategic knowledge demands for the learning task. This problem is especially acute when studies compare learning in electronic and traditional text environments or between different types of electronic learning environments. It is important for such studies to demonstrate that participants are equally familiar with the strategic knowledge for their learning context so that differences in outcomes are not explained by strategic knowledge differences.

Work by Paris and his colleagues (Paris, Lipson, & Wixson, 1983; Paris, Wasik, & Turner, 1991) might be useful for planning training and assessment of strategic knowledge before data are collected. Paris has shown that at least three types of strategic knowledge are important during text processing: declarative knowledge ("knowing that"), procedural knowledge ("knowing how"), and conditional knowledge ("knowing when"). Studies of learning in electronic environments might begin to evaluate participants in relation to these different types of strategic knowledge before treatment. The distinctions Paris draws between different types of strategic knowledge may also be useful to study both the macro- and micro-level strategic knowledge necessary for effective learning in electronic environments.

UNDERSTANDING INTEREST AND OTHER MOTIVATIONAL FACTORS

Interest and other motivational factors have long been recognized as central to both reading comprehension (Thorndike, 1917) and, more recently, to learning in electronic environments (Dillon, 1991). Here we will make four suggestions that might guide future studies investigating motivational factors in electronic learning environments.

First, cognitive theories of learning in electronic environments and, consequently, research based on them, will be enhanced if interest and other motivational factors are placed in a more central position and considered more systematically. In reading research, it is clear that interest and other motivational factors are intertwined with all aspects of comprehension and learning. For example, a number of scholars have begun to focus on connections between strategic knowledge and interest (Borkowski, Carr, & Rellinger, 1990; El-Hindi, 1994; Paris, Wasik, & Turner, 1991), attempting to uncover the reciprocal relation they believe to exist between these two elements of reading comprehension. Others have found close connections between interest and process issues (Schiefele, 1991), and between interest and prior knowledge issues (Alexander, Kulikowich, & Schulze, in press). Interest and motivation are also focal issues for the new National Center on Reading Research (Alvermann & Guthrie, 1993), a group who has used the term "engagement" as a more descriptive and encompassing construct. This focus is beginning to yield important results in theory development, research, and practice.

We believe that a more systematic focus on interest and other motivational factors will yield similar gains for work on electronic learning environments. In our review of this issue, we have found a tendency for studies in electronic learning environments to use limited measures of interest, often just one or two items presented in a Likert scale. These measures were nearly always administered before or after interacting with the learning environment. Seldom was interest measured during a student's interaction with the environment. We believe that more complex measures and more on-line assessment will help to develop a richer, more comprehensive understanding of this important factor.

Second, as we consider the nature of interest and other motivational elements in electronic learning environments, it may be useful to consider the construct of locus of control. Locus of control has been a useful construct in the field of reading, both for explaining differences in achievement outcomes as well as providing important insight into process issues (Hiebert, Winograd, & Danner, 1984; Johnston & Winograd, 1985; Short & Ryan, 1984; Winograd, Witte, & Smith, 1986). The term locus of control has been used to frame learners' attributions for outcomes on cognitive tasks. Learners who attribute outcomes to internal factors, such as effort and ability, are thought to be characterized by internal locus of control. Learners who attribute outcomes to external factors, such as luck or the difficulty of the task, are thought to be characterized by external locus of control. Internal locus of control is associated with higher achievement in reading comprehension, whereas external locus of control is associated with lower achievement (Hiebert, Winograd, & Danner, 1984; Wagner, Spratt, Gal, & Paris, 1989).

Some work has begun to study the role of locus of control in electronic learning environments (Gray, 1989). Given the utility of this construct in explaining learning with traditional texts, it might also be a fruitful variable to study more extensively in electronic learning environments. This is true especially since these environments, because of their potential to support learning, might make it possible over time for students to change external attributions for success (the software environment) into internal attributions (their ability).

Third, as we consider interest and other motivational elements in electronic learning environments, it may be useful also to recognize an important conclusion reached by Alexander, Kulikowich, & Jetton (1994). These authors note that it is important to consider Hidi's (1990) distinction between situational interest and individual interest. Situational interest is specific to the learning situation and transitory; often it is measured after a learning experience. Individual interest is a result of an individual's long-term experiences with a topic or domain and more permanent; often it is measured before the learning experience. It is possible, for example, that individual interest in electronic learning environments actually may impede the acquisition of knowledge (Garner & Gillingham, 1992; Wade & Adams, 1990), especially when students have had extensive experiences with electronic games (Schick & Miller, 1992). Students who come to an electronic learning environment expecting to encounter a game may be less interested in exploring an electronic informational structure to acquire important knowledge. Studies that include measures of interest and motivation need to disentangle these two types of interest if we are to develop a clearer understanding of how interest and motivation interact with electronic learning environments.

Finally, work on issues of interest and motivation should not be separated from work on other issues. Indeed, is only within the context of other issues that we can develop a realistic understanding about the contributions interest and motivation make to learning. A study by Dillon (1991) shows how this is likely to be the case where data emerged by looking at the connections between prior knowledge, process issues, strategic issues, and interest issues. The findings of this study indicated that subjects with more prior knowledge and interest for a topic had more knowledge about the discourse structure of the information environment and that this, in turn, led to more comprehension when reading a hypertext document. In addition, subjects with more prior knowledge also were able to navigate strategically through the hypertext document more effectively and used sections of interest more strategically, both of which facilitated comprehension. We believe that such studies provide important support for the need to study these issues in combination, not in isolation.

CONNECTING READING AND WRITING

Reading research has consistently demonstrated that students learn more when reading and writing are connected (Shanahan, 1990; Stotsky, 1983). There is a long and consistent line of work indicating that combining reading and writing experiences is important for reasons that are cognitive, pragmatic, and social.

Cognitively, it is clear that combining reading and writing experiences results in children who learn to both read and write better (Stotsky, 1983). Because both reading and writing rely on related processes, one activity enhances the other (Shanahan, 1990; Tierney & Shanahan, 1991). This relationship can be exploited effectively in the classroom to simultaneously support cognitive development in both areas. In addition, reading and writing, when integrated strategically into classroom experiences, can be a powerful means to increase students' cognitive ability to analyze and think critically about information. Separately, both reading and writing may be used to develop critical thinking skills but when combined, they serve to reinforce each other and produce even greater benefits than if they are used alone (Tierney and Shanahan, 1991). This is especially

important since critical thinking skills have been increasingly recognized as an important requirement of citizens who wish to participate fully in an economically and interdependent world (Kirsch & Jungeblut, 1986; Langer, Applebee, Mulis, & Foertsch, 1990; National Commission on Excellence in Education, 1983; Ravitch, 1985; The Secretary's Commission on Achieving Necessary Skills, 1991).

Pragmatically, combining reading and writing experiences also is efficient, a quality whose significance should not be underestimated for busy classroom teachers facing increasing demands on instructional time as political units mandate new curricular areas. In addition to increasing learning, linking reading and writing experiences can result in a more efficient use of limited instructional time. This pragmatic aspect of connecting reading and writing often is viewed by teachers as more important than any other (Shanahan, 1990).

Combining reading and writing experiences also says something important to learners about the nature of literacy. Literacy fundamentally is a social and communicative act (Daniels, 1991): readers attempt to understand the meanings assigned by writers and writers attempt to anticipate the meanings assigned by readers (Tierney & Shanahan, 1991). Viewing literacy as a social phenomenon is something that is well known to proficient readers and writers. Failing to integrate reading and writing increases the chance that literacy learners will miss this fundamental aspect of literacy. As a result, they may be less likely to use literacy in their own lives or to use it less effectively when they do read and write.

Taken together, combining reading and writing creates a powerful context as literacy learners simultaneously develop important academic skills, sharpen their ability to think critically about important issues, meet the increasing content area requirements demanded by our society, and acquire insight about literacy as a social and communicative act. Research investigating electronic learning environments needs to focus more attention on simultaneously integrating electronic learning experiences with writing experiences. This is not to say that studies of written composition in electronic contexts are lacking. Clearly, this is an active area for research (Reinking & Bridwell-Bowles, 1991). Nor is it to suggest that the potential of e-mail communication for learning has not been investigated. Clearly, this area is also receiving a great deal of research attention suggesting that communication experiences in writing can support students' learning (Myers, 1993). It is, however, to suggest that we do not yet know much about the ways in which writing experiences *within* a content-focused, electronic learning environment might support learning. Reading research would suggest that this might be a very powerful way in which to assist students and provide important opportunities for critical thinking.

Recently, Leu (1994) conducted an exploratory study into the potential of connecting reading and writing experiences within an electronic learning environment. Reading and writing experiences were presented to fourth grade students within an electronic environment based on a work of children's literature. Several design features were included in the electronic learning environment developed for the study, including a reader response journal, a classroom bulletin board, and an e-mail system.

Reader response journals often are used by teachers to connect reading and writing in classrooms (Nathan & Temple, 1991). As students read a work of literature, they are encouraged to enter their thoughts and reactions to what they are reading in their journal. This activity allows students to draw insights useful to their cognitive development and to engage in opportunities to think critically about the information they are reading. To support students' responses in their journals, this investigation included a set of potential writing ideas that students could access during their reading of the story. At each location in the passage, students selecting this support option would be presented with a list of writing ideas appropriate for that location. Figure 3-3 illustrates one student's entry in her reader response journal in response to a writing prompt.

The electronic learning environment also created communication opportunities between students so they might perceive reading and writing as social processes. When students view reading and writing as social process they, in turn, are more likely to acquire the cognitive and analytic abilities that are central to literacy proficiency (Shanahan, 1990). To accomplish these purposes, the environment included two types of support features: a classroom bulletin board and an e-mail system.

After students had made an entry in their reader response journal, they could keep it to themselves. In addition, however, they could also send it to the classroom bulletin board to be read by others. In so doing, recursive chains of reading–writing connections were developed as students posted a sequence of responses related to the initial item. An example of one entry in a bulletin board location can be seen in Figure 3-4.

The electronic bulletin board encouraged social interaction through reading and writing, as did an e-mail system that allowed students to send messages to one another about their reading experiences or other personal interests. After writing an entry in their response journal, students could send this message to other students in the

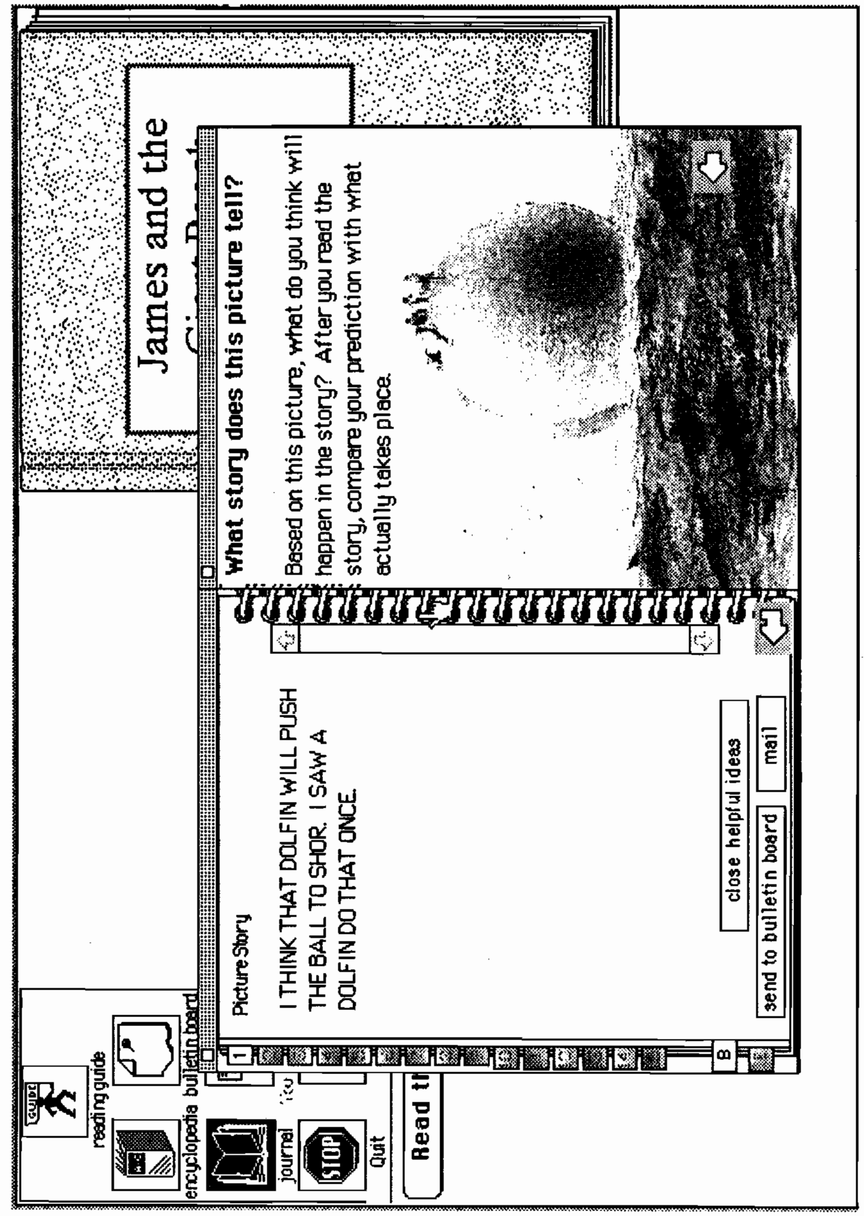

FIGURE 3-3. A view of a screen illustrating one student's entry in her reader response journal.

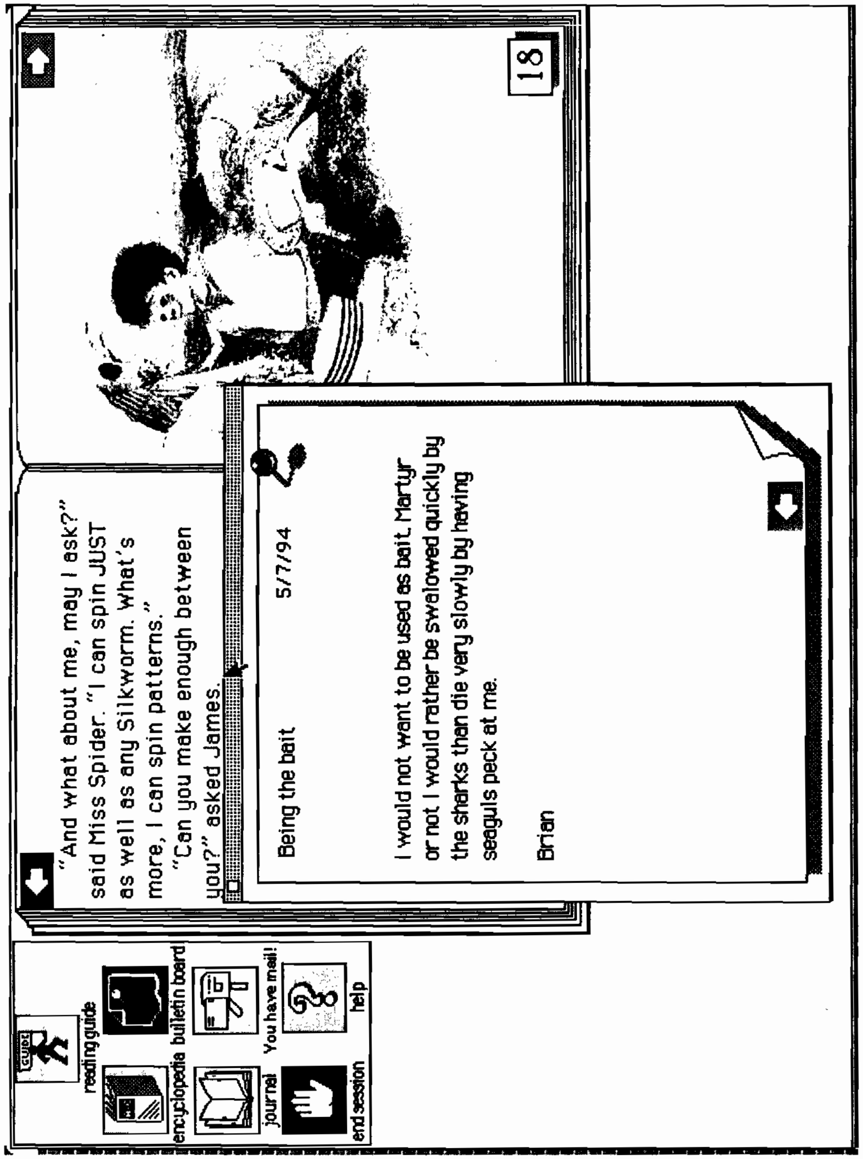

FIGURE 3-4. An example of a bulletin board entry.

class by selecting a button labeled "mail" (see Figure 3-3). Students received messages in their individual "mailbox." Sending messages via e-mail proved to be the most frequently used activity that connected reading and writing. It substantially increased the amount of reading and writing that occurred in this class as each message often led to additional opportunities to read and write. Moreover, written responses to the story that were sent via e-mail typically were deeper and more complex than other types of responses. Each of these patterns confirm the instructional utility of connecting reading and writing with electronic learning environments.

The study also yielded an unexpected, but important, result: Electronic writing experiences provided opportunities for communication between students who did not normally communicate in class. While observing students at the computer, it became clear that communication about the story often took place between boys and girls, whereas such mixed-gender communication was infrequent during regular classroom interactions. Additional communication took place between several exceptional students who were "mainstreamed" into the classroom and other students, something that happened less frequently outside of the electronic learning environment. It appears that when writing takes place within electronic learning environments the potential for socially mediated responses to information increases, especially between students who do not often interact with one another.

This exploratory study suggests that writing experiences within an electronic learning environment might support learning in various ways: by increasing the amount of reading and writing; by encouraging deeper, more reflective response; and by increasing communication between students who might not normally communicate. These tentative findings point to the need for further studies to investigate ways in which reading and writing connections might enhance learning within electronic environments.

EXPLORING THE ADVANTAGES OF RESEARCH AND SOFTWARE DESIGN GROUNDED WITHIN CLASSROOM CONTEXTS

It is important to also recognize that interactive processes transcend relationships between readers and texts or between users and electronic learning environments. Research in reading has recently focused on the classroom interactions between teachers and students as they negotiate meaning in texts. This has been one aspect of the current emphasis on grounding research more systematically in classroom contexts. Another has been a move to see teachers as colleagues in classroom research who have a unique perspective from which to view the complexity of teaching and learning (Allen, Buchanan, Edelsky, & Norton, 1992). Interactions that are more broadly conceived, such as these, have something important to contribute to research on the use of electronic learning environments and to research on the design of instructional software.

It is important to ground research on electronic learning environments within classroom contexts because of a frustrating paradox—at the same time that computers have become more widely available in schools, there is little evidence that they have been widely integrated across the curriculum (cf., Anderson, 1993; Becker, 1990; U.S. Congress, Office of Technology Assessment, 1995; Martinez & Mead, 1988; Reinking & Bridwell-Bowles, 1991). The ratio of students to computers in precollege instruction in the United States has increased from 1 to 30 in 1988 (U.S. Congress, Office of Technology Assessment, 1994) to 1 to 16 in 1993 (Anderson, 1993) and the number of computers available in classrooms increases by about 10% each year. Despite this increase, a recent study (Goodson, 1991) indicates that fewer than 15% of all teachers actually use computers in their teaching. Computer technology is becoming more widely available but it is not becoming fully appropriated by teachers and integrated into classroom learning experiences (Newman, 1991).

This conclusion is also supported by Becker (1993), who reports that although 40% of math and science teachers use some computer software in their classes, only three percent of computer-using math teachers engaged students in the use of graphing programs on more than five occasions and only 1% of computer-using science teachers used computer programs that connected with lab equipment on more than five occasions. It seems clear that teachers are not sufficiently appropriating technology and integrating these experiences into their classrooms, despite the increasing availability of that technology. This paradox suggests a need for research that helps us understand how computers can be fully integrated into classroom instruction.

However, why is it important to seek ways to support more rapid technology integration by teachers? One reason is that technology use appears to profoundly change the way that teachers teach. Technology use appears to foster the development of more student-centered classrooms (Collins, 1990), to increase collaboration among students on learning tasks (Schiengold & Hadley, 1990), and to cause teachers to have higher expectations for students (Schiengold & Hadley, 1990). All of these changes improve the nature of classroom learning environments (The Secretary's Commission on Achieving Necessary Skills [SCANS], 1991).

Yet, just introducing technology designed to positively change classroom practice is not enough. There are also several economic considerations. Anderson (1993) estimates that more than $1 billion per year is spent on hardware and software by schools in the United States. Spending this amount on technology seems to require that we use it wisely to ensure a return on investment. Minimal, sporadic, and isolated use of technology belies the potential for technology to reform education.

One way to make technology more cost effective is to reduce training costs by designing software to fit more precisely the needs of classroom stakeholders. One study (SRI, 1991), has estimated the annual cost of training teachers to use technology to be approximately $900 per teacher or about $4 billion per year. However, this figure is based on current software designs that too often are intimidating to teachers or unrelated to their needs. If software were designed to fit more precisely the needs of classroom teachers, it is likely these costs could be substantially reduced.

We believe that technology use will change dramatically, even among teachers who have been most reluctant to integrate it into their classrooms, when two things happen: (1) more systematic research takes place on the use of electronic learning environments that is grounded within classroom contexts; and (2) electronic learning environments are designed in classroom contexts, not technology labs, in order to be more consistent with teachers' instructional needs.

Recently, Reinking and Pickle (1993) have suggested that "formative experiments" (Newman, 1991) be conducted to understand better how to integrate classroom learning with electronic learning environments. This approach uses both qualitative and quantitative methods to study the effects of changes made within the classroom in how electronic learning environments are used. "In a formative experiment, the researcher sets a pedagogical goal and finds out what it takes in terms of materials, organization, or changes in the technology to reach the goal" (Newman, 1991, p. 10). Such an approach is quite promising. It will allow us greater insight into the effects of changes grounded in the reality of classroom contexts.

It is also possible that such an approach to research could be employed usefully to develop electronic learning environments that meet teachers' instructional needs more appropriately than electronic learning environments designed by technical experts unfamiliar with the reality of classroom life. Currently, teachers are not routinely part of software design teams. Occasionally, electronic learning environments are piloted in schools but only after basic design decisions have been made. Traditionally, it has been expensive to make major changes in design because flexible and powerful authoring tools have not been available. As a result, modifications to software are quite limited and piloting experiences are more often used to assist marketing decisions than for formative development. With the advent of recent authoring tools, however, it is easier to change the design of software and to try out several approaches before making final decisions. The availability of these authoring tools should make it possible to engage in formative approaches to software such that students and teachers can be at the center of design decisions.

By taking a formative approach, electronic learning environments can be designed that are informed by the instructional needs of teachers and the learning needs of students. Formative approaches should enable us to shape classroom learning in ways that take advantage of electronic learning environments and to shape electronic learning environments to maximize learning. Both outcomes are important if we want technology to be both available and used in schools to support learning.

SUMMARY AND CONCLUSIONS

In this chapter we have identified issues we believe may help focus current theoretical perspectives, current lines of research, and current software designs within electronic learning environments. We come to this task from our backgrounds in reading research where the metaphor of an interaction between readers and texts has guided research during the past 25 years. Recognizing that this metaphor is not completely accurate for reading traditional texts, we believe, nevertheless, that the major patterns of this work have something important to say to work in electronic learning environments where more dynamic, responsive, and truly interactive patterns characterize the learning process.

We believe that reading research suggests several useful ideas for guiding work within electronic learning contexts: studying interactive processes as much as products, understanding the role of prior knowledge during interactive processes, understanding the role of strategic knowledge, understanding the role of interest and other motivational elements, exploring the potential for learning when reading and writing experiences are connected, and exploring the advantages of research and software design grounded within classroom contexts. As we put these areas forward for consideration by a wider community, we recognize that our insights are governed, and undoubtedly limited, by our backgrounds in reading research; we do not mean to suggest that these are the only issues that are important. We are convinced, however, that research aimed at understanding electronic learning environments will be limited unless we take advantage of the insights from each of the disciplines that find this environment an important context in which to study learning.

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