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ABSTRACT

In learning environments which provide little structure (e.g., hypermedia systems) students have an especially strong need to regulate and control their own learning. However, a review of the literature indicates that merely providing learners with flexible learning environments does not necessarily mean that they will effectively explore and learn meaningfully from the resources provided. It has been suggested from previous research that poor metacognitive skills, that is the inability to accurately monitor, reflect, evaluate, and adjust learning, hinders learning in this free environment. Metacognitive theory and research are reviewed, and recommendations are made for future research in hypermedia-based instruction and learning. (Contains 71 references.) (Author/JLB)

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Metacognition: Implications for Research In Hypermedia-Based Learning Environment

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ABSTRACT

In learning environments which provide little structure (e.g., hypermedia systems), students have an especially strong need to regulate and control their own learning. Such learning environments should be ideal for enhanced learning. However, a review of the literature indicates that merely providing learners with flexible learning environments does not necessarily mean that they will effectively explore and learn meaningfully from the resources provided. It has been suggested from previous research that poor metacognitive skills, that is the inability to accurately monitor, reflect, evaluate and adjust learning, hinders learning in this free environment. Metacognitive theory and research are reviewed and recommendations are made for future research in hypermedia-based instruction and learning.

Metacognition: Implications for Research In Hypermedia-Based Learning Environment

Hypermedia is an advanced technology that combines film, video, computer graphics, sound, music, and text in a unified information-delivery system centered upon the personal computer (Paske, 1990). The authoring capability of popular products used to develop hypermedia-based instruction makes the development and production processes relatively easy and rapid. Many advantages make hypermedia systems attractive delivery alternatives for both school education and industrial training purposes.

The use of hypertext and hypermedia systems as an effective instructional aid "is premised on a belief in learner control" (Jonassen, 1989; p. 49). For example, the nonlinear nature of hypermedia systems requires users to decide when and where to enter and exit the system, how much information is needed, what kind of information should be selected, where to find it, and what approach is the best. It is apparent that independent decision making, as well as understanding and effectively regulating one's own learning process, is crucial for an individual to successfully exercise the control required by hypermedia-based environments.

For the learner, the advantages of using hyper-based text and media include the ability to augment learning by providing a means to: (a) immediately make connections among a variety of knowledge sources; (b) derive potential relationships among topics of information; and (c) interlock webs of information (Balajthy, 1990). Additionally, from a motivational viewpoint, this mode of presentation can greatly increase the learner's control, allowing for an emphasis on personally relevant topics and/or the elimination of unwanted topics from review. Increased learner control may also lead to learning achievements being more readily attributable to the individual, thus increasing positive perceptions of self-efficacy (Schunk, 1991).

As Jonassen (1989) points out, learner control is an instructional strategy that is grounded on the belief that the learner knows what is best for him or herself and will be more motivated toward learning if given control of learning decisions. However, "the research on learner control has not been supportive" of this premise (Jonassen, 1989; pp. 49). It has repeatedly been shown that learners do not make the best decisions when given control over instruction and in many cases actually learn less than those not given such control (Jonassen, 1989; Williams, 1993).

Several potential explanations may help clarify the gap between the potential learning benefits and the empirical findings. One such alternative is simply that learner control is not an effective approach to learning new material. Given this alternative, it would be hypothesized that a reduction in learner control with a reciprocal increase in program control would lead to increased learning. Findings from studies designed to test this hypotheses, however, have also been inconsistent. Moreover, imposing control essentially negates the flexibility and potential motivational value of hypertext and hypermedia technology.

A second explanation focuses on the possibility that learner control does make a positive difference in learning, but traditional tests of this hypothesis have been inadequate. Both Marchionini (1988) and Jonassen (1988) indicated that new evaluation criteria are needed to assess knowledge structures and student learning in learner controlled hypertext/hypermedia environments. Gleim and Harvey (1992) reviewed and discussed several methodologies that may permit a better view of what actually is occurring within these environments.

A third alternative suggested by several researchers, and the one that is the focus of this paper, is that learners" lack of metacognitive knowledge and skills of the users may hinder their learning in situations of increased learner control (e.g., Balajthy; 1990; Park, 1992; Steinberg, 1989; Williams, 1993).

Metacognition is usually defined as the awareness and active monitoring of one's cognitive processes (Brown, 1987; Flavell, 1987). Individuals with higher levels (or more developed) metacognitive skills tend to plan cognitive actions, recognize personal capabilities, monitor their progress, and reflect upon their own mental processes, as well as regulate those processes (Brown, Bransford, Ferrara & Campione, 1983). Metacognitive skills thus help individuals learn independently, guide their own learning processes, control the selection and sequence of both content and process, and transfer what has been learned to other situations (Rowe, 1988; Lin, 1993). These skills enhance the individual's independent thinking and learning-how-to-learn abilities. Because hypermedia systems rely heavily on learners to make decisions, appropriate inferences, and adjustments to the changing learning environment, it seems plausible that a fairly high degree of metacognitive knowledge and skills would be important for successful learning within such environments.

As hypertext/hypermedia becomes increasingly popular in education and training, there is a greater need for instructional technologists to understand the construct of metacognition and its role in comprehension and learning. Metacognitive skills appear critical to effective use and learning from hypermedia systems and, reciprocally, hypermedia formats may provide a fertile environment for the learning of such metacognitive skills. If effective metacognitive instructional strategies can be incorporated into hypermedia-based learning environments, they may in fact foster the development of good thinkers who are successful problem-solvers and lifelong learners.

The purpose of this paper is to examine research on metacognitive theory and examine its implications for hypermedia-based instruction. The paper (1) discusses the promises and limitations for learning in hypermedia systems; (2) reviews research findings from the field of metacognition; (3) discusses implications of the findings for research in hypermedia learning environments; and (4) suggests areas for future research.

Learning In Hypermedia Environment

The most frequently cited hypertext system capability is the provision of high levels of flexibility and freedom for learners to explore, construct meaning and generate their own learning models (McGrath, 1992). For example, hypermedia systems provide the freedom to navigate through the system in whatever manner the user desires (Kozma, 1991). Such systems also provide means whereby the user can add his or her own information and construct their own relationships (Kozma & Van Roekel, 1986).

Learner control is a basic premise within hypertext/hypermedia environments (Jonasson, 1989). It is left up to the learner, based on his or her goals and previous experiences, to decide what to explore, how, and when to explore it (Roselli, 1991). Because of a wide variety in those past experiences, and in the manner in which individuals learn, it has been hypothesized that "...instruction generally increases in effectiveness, efficiency, and appeal to the extent that it permits informed learner-control by motivated learners" (Reigeluth & Stein, 1983).

Why should the effectiveness, efficiency, and appeal of instructional materials be enhanced through informed learner control? According to Williams' (1993) recent comprehensive review of the learner control literature, instructional effectiveness (i.e., the degree to which the material is learned), may in part be dependent upon the levels of invested mental effort required of the learner. "One might expect a learner-controlled instructional treatment to induce more elaborate mental processing from the students as a result of their pondering the choices with which they are faced" (p. 6). Several theorists argue that greater mental effort increases the probability of meaningful elaboration resulting in deeper comprehension (Salomon,1983; Stein & Bransford, 1979). Additionally, from a constructivist point of view, providing a learning context in which the learner participates in the construction of mental structures, in place of having those structures predetermined, facilitates learning (Ertmer & Newby, 1993; Hartley, 1985).

From an efficiency standpoint, increased levels of learner control allow instruction to be tailored by the individual learner so that it is relevant to his or her own goals and capacities (Roselli, 1991), thus limiting or eliminating redundant or undesirable learning materials and experiences.

Finally, the appeal of instruction and its motivational value should also be affected by the degree of learner control. Steinberg (1989) pointed out that in learner-controlled computer environments, a learner's boredom, frustration, and anxiety should be reduced. Within such environments, when faced with a boring task the learner has the ability to choose to alter and add variety to what is presented. This variety may increase the level of appeal of the instruction (Keller, 1987). Similarly, when unfamiliarity increases feelings of frustration or anxiety, users have the opportunity to postpone exploration of the system to select other materials. Additional motivational benefits of learner control include possible elevated levels of confidence being acquired by the learner (Keller, 1987), increased levels of self-efficacy (Schunk, 1991), and increased levels of continuing motivation (Kinzie & Sullivan, 1989). In each of these cases, the benefits are based on the learner's ability to attribute success more readily to him or herself because of the control over the learning experience.

Although many potential benefits from learner control have been suggested for several years, to date, the research does not support its unconditional use (Williams, 1993). In reviewing the literature on learner control in computer-based instruction, it has been shown that when students are given control over sequence, path, content, pace, etc., their performances are mixed in terms of effectiveness, efficiency and appeal. Frequently, results of learner control studies indicate performance at levels similar to or significantly less than students who are not given controls (Rubincam & Oliver, 1985; Steinberg, Baskin, & Matthews, 1985; Williams, 1993). Rubincam and Oliver (1985), for example, surveyed eleven studies to compare students' achievements in learner-controlled versus computer-controlled situations. Five of the studies showed superior performance under non-learner controlled conditions and only two under learner-controlled conditions. The rest of the studies indicated no differences between the two conditions. Researchers in the area have found that users often exit lessons too soon, view too few examples, and complete the lesson too quickly (Tennyson, Tennyson, & Rothen, 1980; Ross & Rakow, 1980).

Rubincam and Oliver (1985) conducted a study involving a high school CAI algebra lesson. Students controlled the sequence of objectives within each topic and decided whether to take instruction before the test or go to the test immediately. It was found that students who had a consistent selection strategy and a reason for selecting their strategies performed better than those who did not. However, being able to select strategies consistently required learners to know what was best for themselves concerning the task at hand and the environments in which they were studying. Learners had to be able to select effective learning strategies, and to understand when and why those strategies should be used..

In hypermedia-based learning environments, users are given even more control over the instruction than in traditional CAI. Moreover, easy access to the vast quantities of information (Marchionini, 1988), the increased number of learning options available in the systems (Jonassen, 1989), and the richness of the non-linear representation of information (Dede, 1988) can make learning in hypermedia systems extremely challenging and difficult. It is likely to be especially difficult for those users who lack skills in planning, monitoring, reflecting, and regulating their personal learning strategies. The increased complexity and lack of structure of such environments automatically impose increased responsibilities and cognitive processing requirements on users. In these circumstances, it is important for individuals to be able to select and generate strategies to guide their own learning processes and explore thought itself. They should be able to identify (to oneself or others) how a particular strategy came into being, why particular options were chosen, and how particular conclusions were reached. These metacognitive skills enable users to control their own cognitive processing internally. Lacking these abilities, users may become confused and "get lost" in hypermedia systems. They may not be able to discern what they want, where they are in the network, or how to reach any specific point. These problems are known as learner cognitive overload and disorientation (Marchionini, 1988; Roselli, 1991).

Despite the importance of possessing metacognitive skills, they often are not clearly demonstrated by young children or even college students (Wong, 1989). In addition, the overall quality of users' metacognitive skills is relatively poor (Schoenfeld, 1985). It seems that the problems in attaining the potential benefits of learner-controlled learning environments may be attributable, at least in part, to the lack of the learner's use of metacognitive knowledge and skills. In our view, such environments require users to engage in a variety of metacognitive activities, including being aware of the nature of personal learning styles and deficiencies and planning, monitoring, and decision making during learning.

Providing External Support

To fulfill the learning potential in hypermedia-based learning environments, the creation of external supports as a supplement to users' abilities has been advocated. One external support that is frequently used is adaptive advisement, a technique in which the computer is used to diagnose the learner's understanding, prescribe the instructional procedures, explain underlying principles and processes, etc. Another common support is to use graphics, maps, charts, etc., that show students the structure of the knowledge in the system. Designers of hypermedia systems have also used metacognitive aids (on-line ability to save self-generated explanations, highlighting of unfamiliar terms, etc.). Overall, students provided with external supports perform significantly better in immediate tasks, but they do not maintain or transfer their knowledge very well (Steinberg, Baskin, & Matthews, 1985; Steinberg, Baskin, & Hofer, 1986; Tennyson & Rothen, 1979; Tennyson, 1980). In fact, these external supports may themselves be burdens. The so-called metacognitive aids provided within some hypermedia systems (e.g. program-provided explanations of the process one has gone through) are frequently ignored by users and are viewed as additional cogni[illegible] load (Recur & Pirolli, 1992). Marchionini (1988) pointed out that novices use external help to avoid cognitive overload rather than as a way of dealing with it.

These findings support Bernard-Colleta's (1990) contention that, unless learners are directed to be involved in the metacognitive process themselves, many will not automatically engage in metacognitive processes (Brown, Bransford, Ferrara & Campione, 1983). These results suggest that, although external supports can help students solve problems initially, they do not necessarily help learners develop their own strategies and other required metacognitive skills (Steinberg, 1989). Too many external supports may lead students to ascribe the success or failure of their learning to external factors and subsequently take less responsibility for their own learning. Their motivations to develop strategies may even be severely impaired if too many external supports are provided (Steinberg, 1989). Thus, the mere provision of an external support is not necessarily beneficial, at least for long-term retention and transfer, if learners do not understand how it can help, and when, where and why to use it.

Most of the external support discussed above may have lacked the support needed to help learners develop appropriate internal learning-how-to-learn abilities. Learning may not be optimal in hypermedia systems because users have used inappropriate learning strategies

(Steinberg, 1977), because they lack the knowledge and skills or metacognitive skills (Merrill, 1980; Rigney, 1978) needed to make meaningful decisions (Steinberg, 1989; Tennyson & Rothen, 1979) for a combination of these reasons. In reviewing the literature on hypermedia and metacognition for disabled readers, Balajthy (1990) came to similar conclusions. He suggested that poor metacognitive functioning, defined as students' inability to monitor accurately their own success or failure, hindered learning in situations in which students were given control, as opposed to situations in which control was exerted by the computer. Therefore, it is important to look at the construct of metacognition and research findings arising from metacognitive training to suggest how to enhance the effectiveness of hypermedia-based learning environments.

The Need for Learner-Generated Metacognitive Processes

Research related to cognition focuses on how thoughts and internal mental processes influence learning and behavior as well as how these processes take place successfully or unsuccessfully. In the process of acquiring knowledge, a learner applies various "cognitive strategies." For example, a person who must learn to discriminate among several sets of numbers might apply a categorizing strategy to help distinguish one set from the others. An instructor might employ an association strategy at the beginning of a new class in order to memorize the names of students.. Cognitive abilities can thus be regarded as "enabling variables" in that they facilitate performance of specific tasks (Rowe, 1988, p. 228).

Theorists who distinguish between cognitive and metacognitive processes use the term metacognition to refer to those aspects of cognition that require learners to understand their own cognitive processes and to monitor, direct and control them. Flavell, who pioneered the field of metacognition with his exploration of metamemory, describes it this way:

> Metacognition is usually defined as knowledge and cognition about cognitive objects, that is, about anything cognitive. However, the concept could reasonably be broadened to include anything psychological, rather than just anything cognitive. For instance, if one has knowledge or metacognitive. (Flavell, 1987, p.21)

Brown (1987) defines the concept of metacognition as the understanding of knowledge that can be reflected in either effective use or overt description of the knowledge in question. Within the psychological literature, the term has been used to refer to two distinct areas of research: knowledge about cognition and the regulation of cognition (Brown, 1987).

Knowledge About Cognition

For Flavell (1987), metacognitive knowledge consists of three major variables: person variables, task variables and strategy variables. Knowledge of the three variables may influence a person's performance.

Person variables involve knowing about oneself as a learner, e.g., one's cognitive strengths, weaknesses, abilities, motivation, attitudes, etc. In hypermedia-based learning environments, this knowledge will include one's beliefs concerning one's own ability to interact with the environment as well as one's understanding of personal affective states, such as motivation, interests, curiosity and anxiety. Personal knowledge can also include one's awareness of preferred personal learning styles and searching patterns. Realizing that one is frustrated and confused by attempts to solve certain kinds of problems is another example of this aspect of knowledge.

Task variables refer to knowledge about the nature of the tasks, for example, knowing that one task is easier or more difficult than another. Knowledge of task variables implies that the individual knows the type of cognitive demands required in certain instructional settings and how the nature of the task affects the manner in which one should deal with it. For example, a person with an awareness of task variables may know that it is generally more difficult to synthesize information than simply to remember it.

Strategy variables include knowledge of how to use a strategy, or what strategies are available, or how well a strategy works. When an individual knows what strategies are most effective to obtain the best learning results, then he/she is said to possess knowledge about strategy variables. For example, in most learning environments, including hypermedia-based ones, strategically aware individuals might plan ahead of time, monitor their processes, ask themselves why certain steps are taken, and evaluate their performance.

Flavell (1987) suggested that these three metacognitive knowledge variables interact in important ways. For example, individuals might realize or believe that certain types of tasks are very easy or difficult for them and create appropriate strategies that work especially well for them and the task in a certain environment.

Regulation of Cognition

Regulation of cognition is a metacognitive process defined by Flavell (1979) as conscious monitoring that controls and regulates both cognitive and affective processes. Brown (1987) argues that the concept of metacognition consists of activities used to regulate and oversee learning. According to Brown, metacognitive experiences include planning, monitoring, evaluating and revising.

Planning involves determining an overall approach to completing a task or solving a problem, e.g., selecting appropriate strategies, determining what sequence should be taken, and deciding how to evaluate progress while reaching the goals. Monitoring of one's own cognitive processes is the ongoing process that one goes through to track what one is doing and to assess success while implementing plans. Evaluating one's own learning processes involves checking to see what has been done and deciding if the same approach would be good for similar tasks in the future. This process of evaluation can help learners build a repertoire of strategies that they can call upon in the future to address similar situations, and even to generate new approaches in novel situations. Revising one's own learning procedures involves modifying plans, strategies, learning approaches, and goals. In hypermedia-based learning environments, users must be able to plan ahead based on knowledge about their own learning capacities, the task, and strategy. They should be able to monitor their own comprehension of information, evaluate the processes used and the strategies selected to deal with the task, and modify any ineffective strategies and approaches.

Recently, the affective and motivational aspects of learning have received increased attention in the construct of metacognition. Paris and Winograd's (1990) definition of metacognition includes metacognitive judgments, beliefs, and choices. Metacognitive judgments refer to individuals' ongoing assessments of the cognitive characteristics of the learning situation. Metacognitive beliefs involve expectations that reflect affective biases, self-concepts, and motivational disposition. These two components are important because they determine which tasks learners find worthwhile and how they choose to engage them (Paris & Winograd, 1990). Both Schoenfeld's (1985, 1987) and Lockhead's (1985) definitions of metacognition also include awareness of one's beliefs and feelings about the nature of the content domain and the self as a learner.

In summary, metacognitive processes imply active and reflective learners. If cognitive abilities are regarded as "enabling variables," then metacognitive abilities are "organizing and controlling variables" in the sense that they contribute to the selection, sequencing, combination and regulation of cognitive processes (Rowe, 1988, P. 228). As controlling variables, they enable learners to organize and regulate their own cognitive learning processes. They also help learners select and regulate the direction, duration, intensity, range, path, and speed of learning functions (Rowe, 1988; Bruer, 1993). As a result, learners can more thoroughly integrate new information into their existing knowledge schemata, since they are capable of selecting exactly what is needed for their own learning systems. Therefore, metacognitive abilities enhance learners' internal control of cognitive processes and enable learners to function successfully even in situations in which they must make decisions and behavioral adjustments.

Metacognitive Research

Research in metacognition can be organized into two broad categories. The first involves studies which specify how metacognition is developed naturally throughout life; the second concerns the research into the trainability of metacognition. For the purpose of stimulating future research on integrating metacognitive training within hypermedia systems, the second category of metacognitive research is the focus of the discussion here.

Strategy Training Research

The research in this field assumes that the more people know about strategies, the greater the probability they will use the appropriate strategies in the appropriate situations (Vernon & Marie, 1984). Most of the early research has attempted to teach specific metamemory knowledge and strategies. For example, Brown (1978) summarized a series of studies in which mildly retarded children were taught to know when to select missed items when learning a list of words, and when they were ready to recall. She observed from these studies that the training effects were less positive than expected when students were asked to generalize what they had been taught to different situations. She thus recommended that more general metacognitive strategies should be taught.

After reviewing relevant literature on strategy training, Pressley, Borkowski, & O'Sullivan (1984) defined three methods by which individuals may acquire metacognitive knowledge through strategy training. The first is the laissez-faire method in which no training intervention is needed. Learners draw conclusions about the strategies from their applications of strategies. Pressley, Levin and Ghatala (cited in Duell, 1986) did a series of five experiments on the laissez-faire method with adults and fifth-sixth graders. The findings indicated that when performing new tasks after they have been tested, adult learners selected the strategy by which they learned the most, even when it was contrary to what they had been told. Fifth- and sixth-graders tended to persist in using the strategy they were told was better despite the contrary evidence. Only when they were provided information on how the strategies should be used correctly did they select the more effective strategies. It is suggested that a laissez-faire approach is more appropriate for adults than for children (Pressley, Borkowski, & O'Sullivan, 1984).

The second method is explicit provision of metamemory strategies. This method assumes that metacognitive knowledge can be explicitly taught through providing information concerning the utility of a strategy, the importance of the strategy, and information on how to revise the strategy to meet changing task demands. Learners are most likely to use strategies spontaneously when they are given knowledge about what, how, when, where, and why certain strategies should be used (Brown, Campione, & Day, 1981). This information will provide learners with declarative knowledge (what), procedural knowledge (how), and conditional knowledge (when, where and why) of strategies. Pressley, Borkowski & O'Sullivan (1984) examined the effects of this method on transfer. They provided fifth and sixth graders with a memory task (word pairing and Latin vocabulary definitions). The experimental group was provided instruction telling them both when the strategy could be used appropriately and how it could be applied to other situations as well as applying the strategy to three diverse situations. Control group students either were told when and how to apply the strategies or were asked to apply the strategies, but were not given the combined treatment. The experimental group performed better on a transfer test consisting of new vocabulary words.

The third method is metamemory acquisition procedures. It requires learners to understand how the strategy works by experiencing instructions designed to help learners derive information about the strategy being taught (Duell, 1986). This method assumes that learners must be taught to acquire their own metacognitive knowledge. For example, Lodico, Ghatala, Levin, Pressley, and Bell (1983) taught second graders to monitor or evaluate their performances when using different ways of accomplishing the same task. The initial training included suggesting that there were many ways to play a game and in order to play well, "they must select the method that allows them to do better" (p. 267). The subjects were given two tasks, drawing circles and remembering a list of letters. Following each pair of activities, subjects given monitoring instruction were asked questions which made them evaluate their relative performances. This helped them identify which of the two activities was more effective for that task and why. Control subjects practiced the same strategies as the experimental group, but received no feedback and practice on the value of these strategies. Students in the experimental group recalled much better than those in the control group. They also outperformed control group students in giving the reasons for effectiveness of the strategy and selecting appropriate strategy for learning. However, it was also suggested by Pressley, Borkowski, and O'Sullivan (1984) that this method may not necessarily be effective for all training because the memory tasks used were limited to discrete items.

In summary, both children and adults have been taught a variety of metacognitive strategies successfully. Research has demonstrated the effectiveness of informed training, in which learners are told about when a strategy may be used, its application in a variety of situations, its effectiveness for producing better learning, and the modification of inappropriate plans and strategies. Metacognitive strategy training, especially metamemory acquisition training method, has been shown to be successful. However, all of these strategy training approaches should be adopted with caution. Sternberg and Wagner (1982), thus, propose four points that may limit the effectiveness of metacognitive training through strategy training: (1) large-scale training may be impractical and not economic; (2) externally imposed metacognitive strategy training may be less effective than the strategies spontaneously generated by students; (3) students may not elect to use a strategy despite its demonstrated effectiveness; and (4) to be effective, strategies must be so well learned that they do not interfere with actual learning.

<u>Self-Explanation Studies</u>

The majority of self-explanation studies are derived from the metacognitive process perspectives which support the importance of active and self-generative processing of information for a person to become an independent thinker. Learners can develop their own controlling and monitoring systems by providing self-explanations for what they are going to do, their reasons for doing it and how the process has been modified (Campione, Brown, & Connell, 1988). It has also been suggested by several other researchers that self-explanation training can induce independent metacognitive processes, i.e. processes directed at understanding of one's own solution process, rather than relying on outside cues of what has been done and how it has been done, which leads to positive transfer of skills (Alhum-Heath & DiVesta, 1986; Berry, 1983; Berardi-Coletta, 1990). This position implies that explaining one's own processes may help learners obtain declarative knowledge (what), procedural knowledge (how), and conditional knowledge (when, where, why) of the strategies they use during the process of self-discovery learning, which in turn may lead to the development of independent metacognitive abilities.

There are several studies using this approach to metacognitive training which report positive transfer of skills. Most of these studies are from the literature on problem solving. Berry and Broadbent (1987) conducted three experiments with college students in investigating the effects of two different types of explanation training in a computer system on the performance of a complex search task. The task involved determining which of a set of factories was responsible for polluting a river by testing the river for the presence or absence of various pollutants. The two types of explanation training were (1) an explanation provided by the system at the start and the middle of each trial; and (2) a condition in which subjects were allowed to ask "why" each computer recommendation was made. Experiment 1 showed that subjects who received "why" explanations both at the start and the middle points of trials performed better on a transfer task than did subjects who received the explanation only at the start of each trial. Experiment 2 showed that subjects who were required to explain "why" following the explanations provided by the system performed significantly better than did subjects who were required to only explain "why", but received no explanations from the system. Finally, experiment 3 showed that subjects who received multiple "why" explanations and were required to explain "why" at the time when the necessary inferences had to be made were superior on two subsequent unaided transfer tasks. It was suggested by Berry and Broadbent (1987) that the amount, level of specificity and timing of explanation is important for the success of transfer. These studies also indicate that a combination of external and internal explanations is necessary.

Another group of studies on self-explanation dealt with puzzle types of problem solving. Several researchers found that subjects who were required to give reasons for their moves and explain how decisions were made outperformed control subjects on transfer tasks (Gagné & Smith, 1962; Ahlum-Heath & Divesta, 1986; Beradi-Coletta, 1990). These subjects made fewer moves and got more correct answers. It is suggested that predictive explanation about possible performance in hypothetical situations has the worst effects in transfer (Ericsson & Simon, 1980). Retrospective explanation on what one did after the event is little better than the predictive explanation. But, concurrent explanation is the best in helping learning (Brown & Kane, 1988; Chi, Bassok, Lewis, Reimann, & Glaser, 1989).

One possible reason for these results is that requiring problem solvers to explain their thought processes while solving problems "promotes monitoring, planfulness, evaluation and attention to problem features, and the sharpening of such executive processes yields the more efficient performance" (Dominowski, 1990, p.315). Another possible reason is that when learners have reasons for learning, their intrinsic satisfaction and ownership of knowledge will also be enhanced (Brown, 1988; Goodnow, 1988). People will become intentional learners when they have personal interest in learning. Therefore, the above approach may even have a positive effect on motivation so that learners believe deep understanding to be personally valuable and are willing to engage in the self-explanation activities . However, it should also be noted that the process of self-explanation about what one is doing and thinking can be difficult for many college age students, especially in dealing with complicated tasks (Brown, 1978). Additionally, self-explanation can have negative effects on learning when the requirement for self-explanation competes for central processing capacity with the processes that must be reported (Brown, 1987). The following approaches proposed by Gray (1991) may help minimize these problems: (1) start with simple activities so that learners have the chance to practice some metacognitive skills before they attempt more difficult problems; (2) use two levels of self-explanation, first, the steps of the solution process for specific problems should be recorded, and then learners should reflect on what they have learned from this process; (3) teachers should guide at the beginning, providing learners with specific questions to direct their thinking and give them feedback about their responses; and (4) students should be trained to provide explanations before encountering the questions that ask them to state reasons for their processes.

Interactive Intervention Research

This approach emphasizes the importance of social interactions and treating learners as co-investigators in the development of metacognitive skills. A lot of research in this field has taken place within the framework of Vygotsky's (1978) theory of socially mediated learning. The theory assumes that all psychological processes are initially social, shared between people (teachers, parents, peers), and learning is transformed through interpersonal processes (Brown, 1987). Paris and Wingograd (1990) have argued that metacognition is a viable candidate for social interactive learning because insight about oneself can be promoted by other people as well as by self-discovery.

The most often used interactive approach to teaching metacognitive skills is known as reciprocal training that has students interact with experts, teachers, and parents. The process of internalization of learning is gradual from external support to internal regulation. Teachers usually guide the problem solving activities; gradually students and teachers share the functions, with students taking the initiative and the teachers correcting when it is necessary; finally teachers withdraw the guidance to the students and act primarily as a supportive audience (Brown, 1987). Group problem solving and peer interaction, such as discussion and controversy, can also result in deep understanding of what one is learning (Brown, 1988). It is believed that metacognitive experiences are most likely to occur when students are required to explain their views, defend their positions and evaluate their processes to others, especially when they are challenged by others to do so (Brown, 1988; Flavell, 1987; Hatano & Inagaki, 1987). It is when students are forced to explain their positions and reasons to others that they come to understand better and deeper themselves (Hatano & Inagaki, 1987).

Reviewing the literature on interactive teaching methods, Reeve and Brown (1985) described two programs to illustrate this approach. One program was conducted by Palinscar and Brown (1984) on improving high school students' reading skills and the other was by Scardamalia and Bereiter (1982) who researched improving written composition skills. The former had students with varying levels of competence and an adult teacher take turns being the teacher and lead a dialogue on a segment of text. They were jointly trying to understand and remember text with the purpose to engage students in four important metacognitive activities relevant to effective reading: questioning, clarifying, summarizing and predicting events in the text. During the process, the teacher and students gave feedback to each other. As students became more skilled, the teacher decreased her level of participation and acted as a supportive audience. Over a several-week training, students "clearly internalized the types of interactions they had experienced," improving not only the four metacognitive activities, "but also in their ability to assume the role of the teacher, producing their own questions and summaries, and evaluating those of others." (Reeve & Brown, 1985; p. 350). Furthermore, students' feelings of personal competence and control improved dramatically They also concluded that teaching metacognitive skills through direct instruction techniques was far less effective than reciprocal teaching (Palinscar & Brown, 1984).

The second program had novice writers think aloud while writing with the purpose of externalizing cognitive processes involved in writing (Scardamalia and Bereiter, 1982). Students were treated as co-investigators where both instructors and students modeled thinking aloud procedures, presented cues to stimulate self-questioning during the planning stage, and asked strategy questions on how to resolve controversial ideals. The procedures in Scardamalia and Bereiter's study resulted "both in an increased ability to reflect on ideas and in better-structured compositions" (Reeve & Brown, 1985; P. 351).

These results suggest that metacognitive skills can be enhanced through social interactive processes and can be used to improve academic skills. Such social interactive environments can be "supported by computers or other learners, or by both" (Brown, 1988; p. 319).

In summary, improved cognitive functioning has been shown to be related to students' involvement in metacognitive experiences (Brown, 1987). The research from these three metacognitive training approaches has also illustrated that the development of internal self-regulation is central to metacognitive development. Moreover, these studies indicate that any external support, regardless of form, will be effective for metacognitive development only when it becomes internalized by learners. Through the internalization process, individuals will be capable of generating strategies and other support for themselves. Under these enhanced self-management systems, individuals not only learn how to accomplish a particular task, but also learn how to learn (Brown, Bransford, Ferrara, & Campione, 1983). Therefore, no matter what approach is taken, the transition from external-regulated learning to internal self-regulated learning should be the focus for metacognitive training. All of these training approaches should have important implications for research in hypermedia-based instruction.

Implications to Research in Hypermedia-Based Learning Environment

What emerges from the review of the literature on metacognitive research is how learners can be trained metacognitively, how various factors may influence training, how different variables may work jointly to influence metacognitive training, and the cautions that should be considered while employing various types of training. The fundamental importance of the development of metacognitive skills is that learners will be able to guide their own learning process, make appropriate decisions independently and transfer skills to novel situations. As a metacognitive learner, one "can operate as a self-correcting system" (Rowe, 1988; p. 228) and thus is capable of exploring knowledge independently and generating strategies for one's own need. Moreover, metacognition may also enhance learners' motivation and self-esteem. Therefore, metacognitive knowledge and skills are recognized as prerequisite for academic and real life success (Rowe, 1988).

The most often mentioned learning problems in hypermedia systems are learner cognitive overload and disorientation under the situations where learners are required to control their own learning and make decisions independently. It has been suggested by several researchers that students' lack of metacognitive knowledge and skills may be one of the major reasons why learning is hindered in situations where learners are given control (Balajthy, 1990; Steinberg, 1989). When lacking metacognitive knowledge and skills, individuals cannot identify or create strategies regulating their own cognitive processes, and cannot select, adapt, access, combine and process information effectively (Rowe, 1988). If learners are capable of effectively controlling and regulating their own learning processes, they should not be confused by the flexibility and wide array of choices of the hypermedia environment. Therefore, there is a need to identify the implications of the research in metacognitive areas to the learning problems defined in hypermedia systems and suggest directions for future research that merge metacognition into the design and development of hypermedia-based instruction.

One implication arising from metacognitive research is that learner control should be more broadly defined. As described in most computer literature, learner control has been limited to the learners' selection and sequencing of events external to them. However, in addition to the external stimuli, the learners' internal systems are also operating and directing learning events. It is the promoting of internal learner control that needs to be emphasized when talking about resolving cognitive overload and user disorientation problems. Findings from metacognitive research imply that effective and efficient performance is the result of the interaction of learners' internal systems with the external stimuli which have been selected, controlled and regulated by the learners. Those learners who have developed effective internal learning systems may be able to identify what they need and to adjust their selection and control of display, content, or any external stimuli based on their internally perceived needs. Therefore, research on learner control issues in hypermedia systems should also study learner control of internal cognitive processing systems as well as internal codification schema.

Investigations of learners' internal cognitive processing systems should examine whether the learners use the most effective processing strategies available, how learners manipulate their own cognitive activities to adapt into new instructional settings, and what types of mental activities are systematically selected by certain types of learners while interacting with the system. Research is also required to assess the attitudes, motivation and attributes of different types of learners as they use hypermedia-based instruction. Another question that should be answered is how the system can be structured so that the learners will develop more effective adaptive models of their own to enhance performance in a variety of learning situations.

Controlling one's internal cognitive processes is an important aspect of metacognition. Therefore, it is necessary to investigate the types of metacognitive strategies that are important for different types of learners in dealing with specific topics given the structures of the hypermed'a system. What metacognitive skills are lacking in certain types of learners while dealing with specific topics unde specific system structures and why? Among those demonstrated metacognitive skills, which are the most effective for the types of learners, system structures and topics and why? Developmental data are also needed to categorize learners with different metacognitive abilities. These data should include age, maturity, cognitive style, learning experiences with hypermedia systems, motivation and attribution of learning and similar variables.

The findings that simply providing learners with controls over manipulating massive amount of unorganized information, and letting learners explore for themselves, will not be effective in improving learning also has implications for improving metacognitive abilities in hypermedia-based instruction. The real challenge for hypermedia designers and developers is not whether to impose computer control or not, but rather how to take advantage of the technology to help learners develop their own consistent internal learning capabilities to maximize those resources that are available.

A sophisticated hypermedia-based learning system should provide internal adaptive functions of some sort to provide directions for such internal metacognitive developments. Comprehension monitoring and understanding the process of one's own or other's cognitive learning should be encouraged. Providing strategy advice from the system may be ineffective or useless unless learners are informed of what strategies are available in dealing with what types of problems, how to monitor their own use of the strategies, and why, when and where to use these strategies. However, the strategies have to be perceived as important and must be practiced by the learners in order to be effective. Research has shown that learners will not automatically become involved in metacognitive processes unless forced to do so. They may be aware of the need, but do not act upon it. Thus, the systems should try to engage learners in exercising metacognitive strategies as naturally as possible. Feedback provided by the systems should reflect the nature of informed training in which learners are encouraged to find out through self-discovery what, how, why, where, and when certain answers come into being. In summary, any externally provided support or activities should have the potential to facilitate learners to transform from other-regulation to self-regulation of the learning process.

Carefully examining research findings from the metacognitive literature may stimulate ideas for designing effective and efficient hypermedia-based instruction. It is important for hypermedia researchers to identify what types of approaches are the best given certain types of learners in dealing with specific topics.

Instructional technologists should consider how to creatively merge the existing effective metacognitive training procedures into the design and development of effective hypermedia-based instruction in which learners make optimal use of the control available to them. If a self-explanation training approach is taken, it is crucial to determine the amount, the level of specificity, and the timing of the explanations that are necessary for the types of learners, topics, and systems. It is also important to investigate what types of questions human experts ask, what types of explanations they generate, and when. Such investigations may facilitate design of appropriate self-explanation training for hypermedia-based instruction.

If a strategy training approach is taken, it is important to identify the types of strategies that should be taught to certain types of learners in dealing with certain topics, and determine the order in which the strategy training should be delivered. It is also important to find out what types of strategy training (informed, self-discovery, or social interactive) are most effective given the nature of learner, topic and system structure. The major concern in employing a social interactive approach is accountability of group members. Educators continually worry that one member may participate in metacognitive activities while the rest will ride on his or her coattails. How can this approach engage each member successfully in metacognitive training? The importance of motivation and self-perceived competence should also be addressed in any type of metacognitive training. Under what level of control, what types of information presentations and system structures, will learners generate high self-motivations for learning and interacting with the environment? What types of training are effective in improving learners motivation and self-confidence in learning? How will improved motivation affect metacognitive engagement? Finally, it is important to determine the impacts of these metacognitive training approaches on learners' applications of control in hypermedia systems. Will metacognitive training improve content specific and far transfer of learning? Will metacognitive training enhance learners' retention of information and understanding of the relationships among concepts? Will such training impact learners' consistency of strategy application? Will it improve learners' motivation and self-confidence in learning and interacting with hypermedia systems?

Conclusions

The metacognitive research findings are promising and encouraging in support of a positive relationship between learner control situations and learners' improved independent learning abilities as well as their motivation to learn. Findings from metacognitive research imply that learners' internal metacognitive functioning are the key for successful learning under learner control situations. Hypermedia researchers should investigate how to use the technology to help learners develop their own consistent metacognitive systems to maximize the use of the learner control provided by the system. There has not been clear guidance as to how to merge metacognitive theory with the research in hypermedia-based instruction and learning. It is not clear either what types of metacognitive training may be effective for specific types of learners given specific topics and learning environments. Because many fundamental questions related to metacognition and hypermedia-based learning still remain to be answered, the field is a fruitful area for further research and investigation.

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