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ABSTRACT

Defining metacognition as the set of skills and strategies one uses in monitoring and modifying how one learns, this paper addresses ways in which interactive hypermedia/multimedia instructional programs might enhance the meta-cognitive abilities of the learners who use them. It begins by identifying key issues and approaches to metacognition, including the internal and external structures of hypermedia/multimedia products. External structure is described as the ways in which the product assists the learner in gaining access to and making use of the nodes in the product (the internal structure), and strategies for supplying external structure are suggested. Devices for measuring the extent to which learners' metacognitive activities are stimulated, exercised, and developed are discussed, including journal entries, progress logs, transaction shell data, oral discussion, and learner created materials. Specific metacognitive skills are then examined under six broad headings: Task Analysis, Goal Setting, Strategic Action, Cognitive Load, Persistence and Responsibility, and Metacognitive Growth. Within each heading, specific metacognitive skills that might enhance learners' use of hypermedia/multimedia instructional products are examined. For each skill, the paper examines two approaches that hypermedia/multimedia products have used or might use to encourage the development of that skill. The paper next addresses what types of data one might expect to find as evidence of the operation of that skill. Along the way, issues of import in identifying, testing, and evaluating learner metacognition are discussed. (Contains 118 references.) (BBM)

CONSIDERATIONS IN EVALUATING METACOGNITION IN INTERACTIVE HYPERMEDIA/MULTIMEDIA INSTRUCTION

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Part I: Introduction

Goetz (1984) contended that "within the past 20 - 30 years, the cognitive-information-processing view of learning has emerged and . . . learning is seen as the product of complex, interrelated cognitive operations which greatly transform the information being processed" (p. 50). Writers and researchers who adhere to the information-processing model of learning talk about *cognitive load* and the burden that it can impose on learners (Phye & Andre, 1986). Cognitive load is based largely on the limitations of short-term or working memory (Fleming & Levie, 1978; Miller, 1956). Access to increasingly larger and more frequently revised data sets (clusters of related information) makes cognitive overload increasingly more probable and emphasizes the need for efficient and efficacious strategies for examining this material (Charp, 1986; White, 1988).

At the same time, one frequently finds developers of hypermedia and multimedia instructional programs arguing for learner "empowerment" and learner control (Florin, 1990; Hannafin & Rieber, 1989b; Lee, 1990). While such freedom and control may offer learners opportunities to make novel connections and learn in divergent ways (Jonassen, 1991; Marchionini, 1988), it also offers opportunities for them to experience substantial cognitive overload and become disoriented with no sense of location, direction, or purpose (Case, 1980a; Gygi, 1990; Heller, 1990; Morariu, 1988; Oren, Salomon, Kreitman, & Don, 1990).

One scarcely need note that the thinking skills of learners are the focus of frequent, and frequently negative, articles. Learners (and either indirectly or directly, teachers and the educational system) are assailed regularly for learners' reported inabilities to form and test hypotheses, draw conclusions, and evaluate in a critical manner the materials to which they are exposed (Dee & Barkley, 1989; DeBower & DeBower, 1990; Flesch, 1991; Haywood, 1987; Marzano, 1987; Robert, Racine, & Bowers, 1990; Stinespring, 1991). Such concerns about our educational system and its learners are not new, however (see for example, Flexner, 1917; Franklin, 1779; Judd, 1933; Monroe, 1907). As evidence of this longstanding concern, or as a consequence of it, many writers and researchers have devoted their energies to proposing, identifying, or testing new approaches to helping learners enhance their thinking skills. This body of work offers much of value to those considering thinking skills' relation to instructional hypermedia/multimedia products, particularly in relation to Goetz's earlier-mentioned interrelated cognitive processes that transform raw data into meaningful and useful information.

Some writers argue that we need either to develop a new set of skills specifically designed to help learners handle the cognitive demands of the "information age," or to refine and refit current skills to meet those demands (see for example, Card, Moran, & Newell, 1983; Case, 1980b; Cates, 1990; Cates, 1991b; Hannafin & Rieber, 1989a). The global term used to refer to the set of skills and strategies one uses in monitoring and modifying how one learns is *metacognition*. Perhaps the most frequently cited definition of metacognition is that of Flavell (1976):

> Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, *e.g.*, the learning-relevant properties of information or data. . . . Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective. (p. 232)

It appears logical that the skills that might enable learners to make best use of the resources offered by hypermedia/-multimedia products are those skills that fall under the heading of metacognition. How then, should these instructional products stimulate, exercise, and develop learner metacognition?

This paper addresses ways in which interactive hypermedia/multimedia instructional programs might enhance the metacognitive abilities of the learners who use them. It approaches the topic from an evaluative researcher's point of view. That is, this paper seeks first to identify key issues and approaches to metacognition and then examines metacognitive skills under six broad headings: *Task Analysis, Goal Setting, Strategic Action, Load, Persistence and Responsibility*, and *Growth*. Within each heading, specific metacognitive skills that might enhance learners' use of interactive hypermedia/multimedia instructional products are examined. For each skill, the paper examines two ap-

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proaches which hypermedia/multimedia products have used or might use to encourage the development of that skill. The paper next addresses what types of data one might expect to find as evidence of the operation of that skill. Along the way, issues of import in identifying, testing, and evaluating learner metacognition will be discussed.

Part II: Structure and Metacognition

Structure in a hypermedia/multimedia product may be of two types: *internal* and *external*. Internal structure refers to the way in which the *nodes* (individual pieces of information or clusters of information) within the product are organized (*linked*). External structure refers to the ways in which the product assists the learner in gaining access to and making use of the nodes in the product. Using an arbitrary dichotomy, one may divide each type of structure into two levels: *high* and *low*.

Products having low internal structure would be composed of loose affiliations of nodes with few explicit links, or with links whose logical connections were unclear. Many single-link nodes or omni-link nodes might exist in such a product. A single-link node is connected to only one other node by a single link that may or may not be bidirectional. Omni-link nodes are connected to all other nodes in the product either by bidirectional links, or by "near links" that take the learner no more than one or two nodes from the original linked node before offering a return path (link).

Products having high internal structure would employ highly organized node structures, often in either hierarchical or network form. Relationships of dependency, superordinance and subordinance, and ancillarity and auxillarity might well typify the links among nodes (Entwistle, 1981). In the more highly ordered products of this type, multi-linked nodes would be the rule, rather than the exception, and one might expect to find few nodes with single links. One would not expect, however, to find many omni-linked nodes, since it is difficult to create highly structured networks in which such near omni-directionality can occur.

Products having low levels of external structure would incorporate few explicit representations of internal structure, few, if any, advisement or guidance features, and little navigational assistance. In contrast, products having high levels of external structure might well include explicit representations of the internal structure of the product, many advisement and guidance features, and much navigational aid.

Using this taxonomy, one could logically divide products into four possible structural permutations: (1) low internal and low external structure; (2) high internal and low external structure; (3) low internal and high external structure; and (4) high internal and high external structure. Operational concerns and properties of each of these types of products are discussed below.

Low Internal Structure - Low External Structure

Learners would most likely have difficulty representing the contents of such products using logically-ordered arrangements, such as flowcharts, hierarchies, or networks, since the developers had not explicitly designed the products to meet that level of internal structure. One might well find it possible to create representational "fragments," however. Such fragments would represent those nodes for which some logical relationship could be determined or for which some relationship could be inferred. Additionally, one would not expect such products to supply support mechanisms to assist learners in deciphering either the structure of the product or relationships among nodes, since these types of internal structure are lacking or imperfectly understood. Florin (1990) calls such products *data collections*. They may be intended for use as resource materials, but their low levels of structure may impose substantial metacognitive burdens on their learners. These products are often characterized by fruitless searches, learner disorientations, and a tendency to produce disjointed outcomes (Jonassen & Grabinger, 1990; Marchionini, 1988; White, Cates, & Fontana, 1991).

High Internal - Low External Structure

One might expect these products to be logically organized, with linkages that are both logical and multi-directional. If one could ascertain the underlying internal structure, it should be possible to create representations (schemata) that illustrate the nature and organization of both nodes and links. Logical order may well act in opposition to *density* or *complexity* in these products, however. (Density refers to the number of nodes in a product, while complexity refers to the number and interdependency of links among nodes in the product.) While the logical arrangement of the product's nodes may act to make the system "predictable," if the level of density or complexity becomes too great, learners may be overloaded by the quantity of nodes, interdependency of links, or both. In short, a dense or complex network may leave learners unable to grasp the underlying logic and may invite confusion of the "now what was I doing" sort (Gagné & Briggs, 1979; Gygi, 1990; Lanza & Roselli, 1991; Oren et al, 1990). The low level of external structure leaves learners dependent upon their own perceptions of the *moire*, or pattern, of the nodes and links (Heller, 1990). One would expect denser or more complex products in this group to place higher metacognitive demands on learners than less dense or less complex products.

Low Internal - High External Structure

Low levels of internal structure may make it difficult for learners to identify the underlying structure and this, in turn, may make it difficult to ascertain the logic of linkages among nodes. High levels of external structure should provide substantial assistance in using the product, however, provided that the external support supplied is both appropriate and timely. While a high level of external structure should reduce the metacognitive load of these products as compared with comparable products exhibiting low levels of both types of structures, the absence of internal structure may not be easily overcome. That is, learners' inability to perceive internal structure may result in their becoming dependent upon the external structure for guidance and advice. If this proves to be the case, such dependency acts in opposition to metacognition, for metacognitive skill is, by definition, self-sufficient (Gavalek & Raphael, 1985).

High Internal Structure - High External Structure

Products in this group appear to be those best suited to metacognitive development, exercise, and growth. They exhibit both the high level of internal structure that makes it possible for learners to identify on their own the content organization and existing relationships and the high level of external structure that makes that organization and those relationships apparent to the learner. In addition, guidance and advisement features, if properly employed, should facilitate learner metacognitive activity.

The discussions that follow address devices and strategies related to both internal and external structure. While instructional hypermedia/multimedia products that employ both high internal structure and high external structure may appear to be the best candidates for metacognitive stimulation, the discussions that follow should be more or less applicable to products falling into the three other structural permutations as well. The absence of evidence confirming the operation of metacognition, or the present of evidence suggesting metacognitive failure, may tell the researcher much about a product. Perhaps such findings might be interpreted in relation to the combinations of internal and external structure described above. Additionally, the final part of this paper will discuss metacognition and learner dependency on external structure.

Part III: Supplying External Structure: Support Strategies

In a hypermedia/multimedia product, external structure may be supplied to the learner in a variety of ways. For purposes of this paper, these ways will be classified under two categories: *Static/Directive Support* and *Dynamic/Interactive Support*. The two category names are intended to be descriptive of the underlying philosophies and approaches employed by the two types of support. The names were selected on the basis of their definitions. *Static* refers to that shows little change and tends to remain in the same location. *Directive* refers to something that serves to direct, guide, govern, or influence (*Webster's*, 1976). Thus, static or directive support devices would be those evidencing the following characteristics:

1. They are almost always displayed on screen or are almost always available.
2. They are generally under program control rather than learner control (Belland, Taylor, Canelos, Dwyer, & Baker, 1985; Gray, 1987; Ho, Savenye, & Haas, 1986; Kinzie, Sullivan, & Berdel, 1988; McNeil & Nelson, 1991; Yore, 1986).
3. They are usually generic rather than specific in nature.
4. They favor direct instruction over indirect instruction or modeling (Parker, 1991).
5. They are usually displayed in the same form each time that they appear, regardless of the identity of the learner or the number of times they have appeared previously to the same learner.

Dynamic devices are marked by continuous and usually productive activity or change and are noted for being both energetic and forceful. *Interactive* refers to something characterized by mutual or reciprocal action or influence (*Webster's*, 1976). Thus, dynamic or interactive support devices would be ones evidencing the following characteristics:

1. They are usually context-sensitive and appear only when appropriate (Hutchings, Hall, Briggs, Hammond, Kibby, McKnight, & Riley, 1992).
2. They are generally under learner control rather than program control (Hannafin & Rieber, 1989b; Kinzie & Sullivan, 1989; Lee, 1990; Milheim & Martin, 1991; Whitener, 1989).
3. They usually offer specific advice rather than generic advice (Lee, 1991; Wilson & Cole, 1991).
4. They favor modeling and illustration (indirect instruction) over direct instruction (Brown, 1987; Parker, 1991).
5. They may be adaptive across repeated use by a single learner or across different learners (Keller, 1987; Lehrer & Randle, 1987; Ross & Morrison, 1989).

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Part IV: Measurement Devices

This part addresses only the question of how to measure the extent to which learners' metacognitive activities are stimulated, exercised, and developed in instructional hypermedia/multimedia products. It does not address the thorny issue of whether metacognitive activity, in and of itself, produces higher levels of learning of content material. For purposes of this paper, we will assume that learners so stimulated will complete the materials at an acceptable level of performance in ways that meet the objectives or intents set for them, and that they will do so within an acceptable range of completion times. While these are indeed grand assumptions, they are made here solely for the purpose of isolating the issue of identification and measurement from the broader issue of effectiveness. We recognize that effectiveness is a crucial issue. One has difficulty conceiving, however, how one can determine effectiveness until data that might be used as evidence of the operation of specific metacognitive skills have been identified. Thus, the present paper is forced either to tackle untying the Gordian Knot or, as Alexander the Great did, to cut it as a first act (Bulfinch, 1968). If the present work proves useful to others investigating the efficacy question, it will have served its intended purpose (Cates, R.S., 1990).

For purposes of this paper, measurement will be considered in relation to two categories of evidence: *process evidence* and *product evidence*. Process evidence is evidence gathered during the process of learning. Since such evidence often does not produce tangible products, it may normally be overlooked. Pressley, Borkowski, & O'Sullivan (1985) and Slee (1989) argued, however, that this evidence may be of great value in evaluating learner metacognition. Product evidence consists of materials and products that are produced as a result of working through the learning process. Of the measurement devices discussed below, oral discussion is the only one that is used exclusively in gathering process data. The other four devices may be used to gather both process and product data.

Journal Entries

Many hypermedia/multimedia products incorporate an electronic journal function. This journal is actually a small word processor in which learners can write notes to themselves, retain for their own use copies of materials in the product (such as text files or graphic images), or print out copies of materials for use outside the product. If a product does not provide such an electronic journal, one might still use a traditional paper-and-pencil journal to record one's thoughts. There is a long tradition of the use of journals in a variety of subject areas, particularly the humanities, and the inclusion or use of journals is often justified on the grounds that it encourages "reflection," "insight," or metacognitive awareness (Bransford & Vye, 1989; Collins, Brown, & Newman, 1989; Glatthorn & Baron, 1985; Jones, 1992). Journal entries or notations, whether they be recorded electronically or mechanically, seem to offer a legitimate source of evidence of metacognitive activity.

Analyzing journal entries as evidence of metacognition is not without problems, however. First, researchers analyzing such data will need to establish clearly which types of entries and notations are indicative of which types of metacognitive activity. This introduces a large measure of subjectivity in analysis, but subjectivity is not necessarily problematic, provided that researchers make clear the bases for their interpretations (Bogdan & Biklen, 1982; Borg & Gall, 1989). Second, learners may not be conscientious in writing in their journals. If they are not, much data that might illustrate metacognitive activity may go unrecorded. Third, learners may lack candor in their entries, particularly if they know or think that their entries may later be the subject of another's scrutiny. Fourth, learners may lack the maturity, insight, or writing skills to express what it is that they are thinking or feeling. If this proves true, their journal entries may offer an impoverished resource for researchers. This impoverishment may be further complicated if journals are maintained electronically, since for some students the impediment of keyboarding or using the features of a word processor may be inhibiting. The added mechanical load may make it difficult for these students to concentrate on their own mental operations when almost all of their spare mental capacity is consumed by the mechanical task of making journal entries (Phye & Andre, 1986).

Progress Logs

Many programs are capable of maintaining a record of where learners are at present and where they have been. Often hypermedia/multimedia programs maintain this record in the form of "recent" maps. Such data may be recorded on disk as progress logs for later analysis. These logs may allow researchers to reconstruct the paths learners take through a program and can help researchers infer the metacognitive activity involved.

Transaction Shell Data

Similarly, there are programs called transaction shells which operate in the background while a learner is working with a program. Transaction shells are not only capable of recording where a learner has been, but also what he or she did while there. These "transactions" can then be examined with an eye to inferring or deducing which mental activities (and more specifically, metacognitive activities) appear to account for what the transaction shell data show.

Oral Discussion

A fourth source of data on metacognitive activity may be oral comments made by the learner, either in conversation or in isolation. Day, French, and Hall (1985) argued that metacognitive skills are refined in social interaction. This contention finds much support in the professional literature (Baecker & Small, 1990; Baron & Kallick, 1985; Bransford & Vye, 1989; Brown, 1987; Costa, 1985a; Gavalek & Raphael, 1985; Moss, 1990; Prawat, 1989). One source of such refinement may be the use of cooperative groups which interact with one another while working on computer (Dalton, Hannafin, & Hooper, 1989; Del Marie Rysavy & Sales, 1991; Gomoll, 1990) Photographic, videotaped, audio-recording, or simply overheard versions of these oral transactions offer rich sources of research data (Baron & Kallick, 1985; Tucker & Dempsey, 1991).

Learner-Created Materials

Learners may create a variety of materials for their own use as they work through hypermedia/multimedia products. These materials may also present rich sources of data for researchers.

Part V: Specific Metacognitive Skills: Support Strategies and Possible Evidence of Metacognitive Activity

This part of the paper addresses eleven specific metacognitive skills falling into six broad categories. A separate section will be devoted to each of the six broad categories. Each section will utilize a similar structure of subsections. The section will begin by identifying a metacognitive skill. The next two subsections will identify specific ways in which an instructional hypermedia/-multimedia product might address this skill, first using static/directive support and then dynamic/interactive support. The next two subsections discuss anticipated evidence of the operation of the metacognitive skill: process evidence and product evidence. The final subsection for each skill discusses any concerns related to skill. If a section contains more than one metacognitive skill, each skill is addressed in the manner described, in turn, before going on to skills in the next one of the six broad categories. Where appropriate, relevant references are cited.

Task Analysis

Skill: ***Recognizing the size and scope of a task*** (Greeno & Riley, 1987; Lawson, 1980).

Static/Directive Support:

The key issue here is helping the learner to get an adequate image of the internal structure of the product, while at the same time focusing the learner's attention on the specific task at hand (Psotka, 1991). Support devices that might serve this purpose include various forms of advance organizers. Promising advance organizers include:

1. Outlines of the steps or stages in the task (Krahn & Blanchaer, 1986);
2. Content maps that attempt to make clear the interrelationships of the content to be examined (Collins et al, 1989; Heller, 1990; Marchionini, 1989);
3. Learning objectives that specify exactly what the learner is to accomplish and how accomplishment is to be demonstrated (Hannafin & Rieber, 1989b; Ho et al, 1986);
4. Supplied schedules or time estimates designed to help the learner project how long it will take to complete the task (Cates, 1991c);
5. Adjunct questions that call for learners to formulate schemata (Gordon & Braun, 1985; Schloss, Sindelar, Cartwright, & Schloss, 1986).

Dynamic/Interactive Support:

The key here is helping learners monitor their progress toward completion of the task. One promising approach would be for the program to monitor the learner's progress and the amount of time expended. The program could then compare these data to averages of time and progress and offer advice to the learner on the basis of these comparisons. The intent here is to alert the learner to the rate of progress and to offer advice that clarifies the scope of the task. Perhaps such advice should be modeled on the performance of three types of learners: beginner, intermediate, and expert. The advice could then be based on the match between the present learner's progress and that of the models (Carrier & Jonassen, 1988; Hannafin & Rieber, 1989b; Keller, 1987; Psotka, 1991).

Process Evidence:

Transactions: Evidence that the learner is exercising this metacognitive skill in the process of completing the task would be records of transactions involving advance organizers which were available. Repeated access to such

advance organizers, particularly those related to scheduling and time estimates might be particularly diagnostic, as might access to such devices anytime the learner resumes work on the task following a break.
Oral: Process evidence here might consist of discussions or comments about the nature and scope of the task. As is the case with all oral data, such discussions or comments might occur in teacher-student interactions, in cooperative student task groups, in isolation, or in incidental conversation.

Product Evidence:

Journal: Journal notes or entries referring to the nature, scope, or size of the task suggest the operation of this skill.
Learner-Created: Learners might draw representations of the task or attempt to create their own reconceptualizations of the task at hand. Such representations, whether formally drawn or merely sketched out, suggest the operation of this metacognitive skill (Goetz, 1984; Hannafin & Rieber, 1989a; Kearsley, 1988; Young, 1983).

Concerns:

An obvious concern here is that time and progress comparison values will be difficult to derive and, regardless of the accuracy of the comparison values, metacognition is not a comparison-based activity. In other words, consider for a moment the expression "His mill grinds slow, but it grinds exceedingly fine." Speed is not automatically a measure of excellence, nor should it be assumed to be a measure of metacognition. Learner models will need to be well-designed and highly generalizable if they are to be valid and useful.

In order to make the most of the devices and advice offered, learners need at least minimal awareness of their own task behaviors (work habits, rate of progress). Otherwise, they may not recognize which advice to take and which to ignore (Cates, 1991b). Similarly, learners may need training in advance in order to know how to draw representations and reconceptualizations (Card et al, 1983).

Goal Setting

Skill: ***Setting appropriate goals and subgoals*** (Goetz, 1984; Greeno & Riley, 1987; Prawat, 1989).

Static/Directive Support:

The program could suggest formal goals and subgoals (Baird, 1988). It might use direct instruction to point out how goals and subgoals contribute to completion of the task.

Dynamic/Interactive Support:

The program could offer the learner a selection of possible goals and related subgoals, allowing the learner to select among them as desired. The program would then retain a record of the goals and subgoals selected and could tailor the advice it offers to the selected goals and subgoals (Keller, 1987; Zellermayer, Salomon, Globerson, & Givon, 1991).

Process Evidence:

Transactions: Indications of the operation of this metacognitive skill might include access or repeated access to formally presented goals or subgoals, selection of goals and subgoals from an offered list, or access to offered advice on goals and subgoals.
Oral: Comments or discussions relating to goals or subgoals suggest metacognitive skill activation.

Product Evidence:

Journal: Entries or notations would address goals and subgoals. Such entries might merely list them, or might comment on their formation.
Learner-Created: Hierarchical layouts or network illustrations of the relationships of goals and subgoals suggest initial metacognition in goal setting.

Concerns:

Before we can expect learners to participate in setting goals, they must understand what goals and subgoals are, and how they relate to one another in leading to the accomplishment of a task. Learners may also need to be taught how to represent goals and subgoals in hierarchies and networks as part of their understanding of how they are related (Glynn & DiVesta, 1977).

Skill: ***Revising goals and subgoals as necessary*** (Gavalek & Raphael, 1985; Glatthorn & Baron, 1985; Wellman, 1985).

Static/Directive Support:

The program might provide learners with the ability to view goals and subgoals as they work toward completion of the task (Wolz, McKeown, & Kaiser, 1989). This might be accomplished by a goals/subgoals icon that permitted the learner to review goals and subgoals as desired (Cates, 1991c). Through an intervening coach, the program could impose external evaluation of goals and subgoals with mandated revisions (O'Shea & Self, 1983; Marchionini, 1989; Poppen & Poppen, 1988).

Dynamic/Interactive Support:

The program could monitor learner progress and suggest revisions at appropriate points. The locations of these revisions points, the bases for monitoring learner progress, and the nature of the advice to be offered could once again be based upon comparison to the three learner models discussed earlier (Yordy, 1991). The program could also pose a series of questions designed to help the learner assess the adequacy of the goals and subgoals currently selected (Bellanca, 1985; Costa, 1985a; Day et al, 1985).

Process Evidence:

We would expect to see repeated access to goal and subgoal statements and to hear oral comments and discussions questioning the adequacy and appropriateness of those goals and subgoals.

Product Evidence:

Journal: Entries and notations would address the adequacy of the goals and subgoals selected and might suggest revisions.
Transactions: The learner would have reselected goals or subgoals or substituted a new set of goals and subgoals.

Concerns:

Learners need experiences in judging the adequacy and appropriateness of goals and subgoals. This will require many instances of exercise followed by debriefings. While this may occur in using hypermedia/multimedia products, it is unlikely that the computer program can do an adequate job of debriefing, and thus teacher intervention will be required (Cates, 1991b).

Strategic Action

Skill: ***Selecting appropriate learning strategies*** (Derry, 1985; Derry, 1989; Lawson, 1980; Pressley et al, 1985).

Static/Directive Support:

The program could prescribe strategy. It could supply direct instruction in how to select and use strategies (Beyer, 1991; Parker, 1991). It could impose strategy through an intervening coach (Bransford & Vye, 1989; O'Shea & Self, 1983).

Dynamic/Interactive Support:

The program could offer strategic advice (Gavalek & Raphael, 1985). It could offer learners opportunities to view modeling of strategic actions (White, 1989). The program could pose questions designed to help focus the learner's attention on the key selection issues (Collins et al, 1989).

Process Evidence:

Transactions: There would be evidence of learners having gained access to offered presentations on strategy or advice on strategic actions.
Oral: Learners would comment on or discuss possible learning strategies.

Product Evidence:

Journal: Entries or notations on learning strategies would appear.

Concerns:

Learners may have difficulty grasping what each strategy does and what makes a strategy appropriate in one context and not in another.

Skill: ***Determining the effectiveness of a learning strategy or set of strategies*** (Derry, 1985; Derry, 1989; Goetz, 1984; Lawson, 1980; Presseisen, 1985; Wellman, 1985).

Static/Directive Support:

The program could provide generic introductions on the use of strategies. It could provide direct instruction on evaluating strategies (Beyer, 1988).

Dynamic/Interactive Support:

Once again, the program could offer strategic advice or offer learners opportunities to view modeling of strategic evaluations (Costa, 1985a). The program could pose questions designed to help focus the learner's attention on key effectiveness issues (Bellanca, 1985; Day et al, 1985; Merrill, 1987).

Process Evidence:

Transactions: There would be evidence of learners having gained access to offered presentations on strategy or advice on strategic actions.
Oral: Learners would comment on or discuss the adequacy of presently-employed strategies.

Product Evidence:

Journal: Entries and notations would address or document the adequacies or inadequacies of learning strategies employed. Journal comments might also allude to encountered difficulties, thereby suggesting the learner's growing awareness of strategic insufficiency.

Concerns:

Learners must understand strategic applications and how to determine when a strategy is producing the desired results (Cates, 1991a; Cates, 1991b).

Skill: ***Revising a learning strategy or set of strategies as necessary*** (Derry, 1985; Goetz, 1984; Greeno & Riley, 1987; Lawson, 1980; Presseisen, 1985; Pressley et al, 1985).

Static/Directive Support:

Once more, the program could provide generic introductions on the revision of strategies. It could provide direct instruction on revising strategies. It could use an intervening coaching function to impose revisions (Bransford & Vye, 1989; Marchionini, 1989; Poppen & Poppen, 1988).

Dynamic/Interactive Support:

Again, the program could offer strategic advice or offer learners opportunities to view modeling of strategy revision (Beyer, 1991; Derry, 1989). The program could pose questions designed to help focus the learner's attention on the key revision issues (Day et al, 1985).

Process Evidence:

Transactions: There would be evidence of learners having gained access to offered presentations on strategy or advice on strategic actions.
Progress Log: The progress log would indicate purposeful backtracking to suggest that a new learning strategy was being applied.
Oral: Learners would comment on or discuss changes to current learning strategies.

Product Evidence:

Journal: Entries and notations would comment on changes in strategic approach.
Transactions: The learner's pattern of access would change to suggest a revision in strategy. If the learner's previous strategy or set of strategies had been entered and retained by the program, the retained strategies would now be different.

Concerns:

Learners often may become committed to strategies and may not realize that they can change them any time that they wish. Learners may believe that they must complete a learning episode before being able to revise their strategies.

Cognitive Load

Skill: ***Minimizing cognitive load, particularly memory load*** (Card et al, 1983; Cates, 1991a; Cates, 1991c; Florin, 1990; Keller, 1987; Phye & Andre, 1986).

Static/Directive Support:

The program could maintain key information on the screen and on-line help would be available (Brown, 1988). The program might make content available through multi-linked nodes. The program could maintain a record of learner position and make a "recent" map (or a similar device) available (Cates, 1991c).

Dynamic/Interactive Support:

The program could offer advice on sequence, path, or both. It could match its advice to the intentions and wishes of the learner. Advice would be "localized" or "compartmentalized" so that it suits exactly the context in which it is sought (Brown, 1988; Oren, 1990). Learners would not be presented with more material than they requested. When learners asked for advice or explanation a second time, that advice or explanation would be rephrased (Hutchings et al, 1992). Where possible, the program would employ multi-sensory (dual) encoding, usually through combinations of text, graphics, and sound (Florin, 1990; Oren, 1990).

Probably the best way to identify cognitive sufficiency is by noting the absence of cognitive overload. Cognitive overload might be indicated by the following types of evidence:

Process Evidence:

Transactions: There would be little evidence of recursive backtracking. Learners would not have viewed either "recent" maps or any programmed versions of internal structure. Students would not spend extensive periods of time reviewing electronic journals.
Oral: There would be few oral requests for assistance and few expressions of confusion or disorientation by learners.
Learner-Created: Learners would not spend long periods of time reviewing internal structure representations they have created or consulting and reviewing entries in paper-and-pencil journals.

Product Evidence:

Journal: Cognitive overload might be suggested by learners entering notations expressing concerns about confidence or expressing confusion about the features or operation of the product. Such evidence is a negative (contra-) indication of cognitive sufficiency.
Learner-Created: Cognitively-overloaded learners might create memory aids. Such aids could include representations of the internal structure of the program or "quick reference" cards to assist them while they're using the program. Once again, this type of evidence may be viewed as "negative evidence" suggesting that the program is failing to meet the learner's needs and that these learner actions are taken "in self-defense."

Concerns:

Learners need to learn memory "tricks." They may also need to become accustomed to the program's demands. Learners will need to determine the optimum combination of their own memory aids and the computer's external support mechanisms.

Persistence and Responsibility

Skill: ***Recognizing the scope of mental effort required and distributing mental effort across the task as appropriate*** (Costa, 1985b; Falhikov & Boud, 1989; Hannafin & Rieber, 1989b; Iran-Nejad, 1990; Milheim & Martin, 1991; Presseisen, 1985; Pressley et al, 1985).

Static/Directive Support:

The program could provide information on the time demands and the relative difficulty of material to be covered. This information might be in the form of time indicators (for example, clocks, stopwatches, calendar pages) (Cates, 1991c) or a difficulty rating score (perhaps from 1 to 10). The program could display progress gauges to inform learners of progress (Baecker & Small, 1990; Brown, 1988).

Dynamic/Interactive Support:

The program could provide encouraging comments as the learner works through the task (Costa, 1985a; Derry, 1989). The program's coach might offer advice or guidance on how to handle tasks. The program could offer presentations in which an experienced learner describes (models) how he or she persisted (Beyer, 1991; Florin, 1990). The program could employ adaptive difficulty levels as a way of assisting learners having troubles with persistence. Such adaptation might be under learner control (perhaps through a prompt and selection option) or could be automatically triggered by some symptom or set of symptoms that suggests flagging persistence (Marchionini, 1989; Zellermayer et al, 1991).

Process Evidence:

Transactions: Persistence on task would be evidenced by few breaks and response latencies and by times between screen changes which were comparable to those of learners who work consistently and persistently.
Oral: Discussions would be focused with little sidetracking and few purely social interactions.

Product Evidence:

Journal: Entries and notations would reflect persistence and continuing effort. Entry dates or times would reflect a distribution of effort across the task.
Progress Log: The progress log would show continuing progress toward the goal.

Transactions: If items designed to test acquired knowledge or skill were embedded in instruction, learner performance on these items would be generally consistent across all aspects of the task.

Concerns:

Lower ability learners or learners with lower levels of self-confidence or self-esteem may be easily discouraged. Computers programs are not ideally suited to providing the "warm" human support that such learners may need.

Skill: ***Taking personal control and responsibility for learning*** (Falhikov & Boud, 1989; Keller & Keller, 1991; Prawat, 1989).

Static/Directive Support:

The program might use phrases and expressions that emphasize the centrality of the learner. For example, instead of having the program ask the learner to indicate "your choice" of some options, it could have the learner indicate "my choice" of options. In short, language used in the program would be learner-referenced whenever possible. The program would also evidence a philosophy that the learner is an active participant. This would be most noticeable once again in phrasing, where the program would use active phrases for learner actions. So, instead of stating "You will be asked to select one of the following and the program will then supply you with related materials," the program would state "Make your selection to view related materials" (Keller & Suzuki, 1988).

Dynamic/Interactive Support:

As was the case above, the program would use learner-referenced language and would assume an active-learner philosophy. The program would offer choices, not impose decisions (Yordy, 1991). The program would be obedient, cooperative, and non-intrusive (Brown, 1988; Keller, 1987).

Process Evidence:

Once again, learners would exhibit signs of persistence on task (see above). In addition, they might be expected to use first person pronouns and possessives in oral discussions when referring to their progress. In general, overheard comments would evince a sense of control and responsibility.

Product Evidence:

Journal: Entries and notations would voice a sense of responsibility for completion of the task, a sense of control (effort related to outcome), and would not attribute outcomes to the behavior or control of others, nor would they express feelings of helplessness (Cates, 1981; Cates, 1991b).

Concerns:

It is not enough for the program to use the "correct" kind of language if it does not actually "practice what it preaches."

Metacognitive Growth

Skill: ***Analyzing the success of a learning outcome*** (Iran-Nejad, 1990; Presseisen, 1985; Wellman, 1985).

Static/Directive Support:

The program could maintain records of learners' previous performances and these records would be available to them.

Dynamic/Interactive Support:

The program could comment on learner success (Costa, 1985a). Learners could be debriefed by a teacher or peer using questions and oral discussion (Baron & Kallick, 1985; Wilson & Cole, 1991). The computer might initiate or facilitate this debriefing process by printing out a "debriefing log" that details strategies, progress, and other relevant information which might assist in the debriefing.

Process Evidence:

Transactions: The learner would have referred to records of previous performances.
Oral: Learners would participate in discussions of strengths and weaknesses of their task performance and might discuss their perceptions of success.

Product Evidence:

Journal: Entries and notations would refer to evaluation of performance in completing the task. Journal comments might directly address perceptions of success or failure.

Concerns:

Some learners may define success as simple completion or as escape from the task (Prawat, 1989). Others may feel they have failed even when their performance is acceptable because they compare themselves to more-expert models presented by the program or by the person doing the debriefing (Iran-Nejad, 1990). A common definition of success must be mutually agreed-upon in advance (Keller, 1987).

Skill: *Generalizing from one learning episode to others* (Falhikov & Boud, 1989; Gavalek & Raphael, 1985; Glatthorn & Baron, 1985; Tobias, 1989; Wilson & Cole, 1991).

Static/Directive Support:

Once again, the program could maintain records of learners' previous performance and make these records available to learners (Caffarella, 1987).

Dynamic/Interactive Support:

The program could comment on learner success or cite earlier performances. Learners could work with a teacher or peer using questions and oral discussion to determine exactly what lessons have been learned from the experience. In such sessions the results of several learning episodes might be reviewed and a general principle to account for the performance in these episodes might be formulated (Cates, 1991b; Costa, 1985b). The computer "debriefing log" mentioned above might help in discussing multiple episodes, as might learners' journal entries.

Process Evidence:

Transactions: The learner would have referred to previous performance records.
Oral: Learners would discuss extensions of practices and strategies used in the present learning episode.

Product Evidence:

Journal: Entries and notations would discuss possible extensions of the practices and strategies used in the present learning episode.
Transactions: If the learner had employed strategies or approaches not covered in the present learning episode, one might infer that he or she had generalized such strategies from previous learning episodes.

Concerns:

We cannot know for sure if learners are generalizing from one learning episode to another unless we have opportunities to observe learners across multiple learning episodes.

Part VI: Conclusions

This paper has examined metacognition, ways in which instructional hypermedia/ multimedia programs might stimulate, exercise, or develop specific metacognitive skills, and the types of evidence we might expect to confirm the operation of each skill. This paper has attempted to consolidate a broad body of literature and to synthesize and apply it in new ways. The work started here is clearly foundational; it is intended to assist in extending research in metacognition to hypermedia/multimedia instructional environments. Before this paper concludes, there is one reservation about metacognition and learner dependency that should be noted.

Gavalek and Raphael (1985) contended that "it is the transfer of control from another individual to the learner himself or herself that is one of the primary criteria suggested for determining whether metacognition is involved" (p. 111). In a similar vein, Wolz et al (1989) wrote, "While initial learning may require extensive supervision, once the key concepts are learned, users are expected to initiate their own goals and solicit expertise from others only when necessary" (p. 55).

It is unclear whether external support structure actually stimulates metacognition or merely substitutes for it. Derry (1985), Day et al (1985), and Wellman (1985) expressed concern that learners might well become dependent upon the presence of the external structure and would not, therefore, attempt to internalize the skills. In fact, Yore (1986) and Whitener (1989) both concluded that too much external structure could actually inhibit metacognitive development by short-circuiting the process by which learners formulate their own strategies. Kozma (1987) disagreed, however, arguing that external structure can only help learners develop their own metacognitive skills. More research on metacognition and external structure is needed. If we are to meet Gavalek and Raphael's dictum that control be transferred to the learner, researchers must attempt to identify techniques that exercise and develop students' metacognitive skills to the point where learners are no longer dependent upon the presence and aid of external structure.

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