Metacognition: Definitions and Empirical Foundations

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A diligent twelfth-grade student sits attentively in her pre-calculus class trying to follow the teacher's first lesson on the fundamental theorem of integral calculus. The teacher is using the analogy of finding the area under the sinuous track of a roller coaster to instruct the concept of area under a mathematically defined curve. The steel girders holding up the track circumscribe rectangular columns whose widths can become increasingly smaller, and with increasingly smaller widths a closer approximation of the total area under the track can be obtained. Our student recalls the section in her mathematics textbook that she studied the night before, and she is beginning to make the connection between the textbook's presentation and the teacher's analogy. She knows how to calculate the area of a rectangle, and she understands how she can use what she knows to find the total area under the track by adding all the rectangular columns of area under the track. However, she has not quite arrived at how the total area would be affected by making the widths of the columns increasingly small. She realizes that she does not understand, and she tries to increase her concentration on the teacher's explanation and on the diagram of the roller coaster drawn on the blackboard. Unfortunately, her attempts to increase concentration are failing because two students sitting behind her are distracting her with whispers about what happened to a mutual friend over the weekend. And to add to her difficulties, the teacher's use of the roller coaster analogy has reminded her of last summer's vacation to Disneyland. Memories of the fun she had there on the roller coaster are further interfering with her thoughts of the problem at hand. She decides to redouble her concentration and is able to filter out the students' whispers. She then also realizes that her memories of Disneyland can be used if she focused attention specifically on memories of the superstructure that supported the roller coaster. Her insight, however, is interrupted when she hears the teacher tell the class to take out a piece of paper for a surprise quiz on the material just covered. Our diligent student is hit with a sinking feeling in her stomach because she knows that she did not understand the lesson, and her poor performance on the quiz will likely bring her average for the course down to a "C."

Many of the thoughts and feelings experienced by this twelfth-grade student as she attempts to take charge of her learning can be described as metacognitive: realizing she does not understand; deliberately increasing her concentration to block out environmental distractions; and consciously using her memories of Disneyland to progress toward understanding. What makes these thoughts or feelings "metacognitive" as opposed to simply cognitive is not easy to describe (Nelson & Narens, 1990). Descriptions are difficult because metacognition by its very nature is a "fuzzy concept" (Flavell, 1981, p. 37), which has been made even fuzzier by a ballooning corpus of research that has come from researchers of widely varying disciplines and for widely varying purposes.

The purpose of this chapter is to cut through the fuzziness surrounding the concept by describing the characteristics of metacognition that have remained relatively constant across disciplines and purposes since John Flavell's pioneering work helped give form to the concept and whose call for research provided an impetus for its study. In addition, greater understanding of metacognition can be gained by knowing how it has been investigated. Therefore, a brief review will be given of the ways in which metacognition has been operationalized and investigated. By attempting a definition of metacognition and describing how researchers have come to know the concept, some of the fuzziness should be resolved.

Flavell's Contribution

It [memory development] seems in large part to be the development of intelligent structuring and storage of input, of intelligent search and retrieval operations, and of intelligent monitoring and knowledge of these storage and retrieval operations -- a kind of 'metamemory', perhaps. Such is the nature of memory development. Let's all go out and study it!1 (Flavell, 1971, p. 277)

What is basic to the concept of metacognition is the notion of thinking about one's own thoughts. Those thoughts can be of what one knows (i.e., metacognitive knowledge), what one is currently doing (i.e., metacognitive skill), or what one's current cognitive or affective state is (i.e., metacognitive experience). To differentiate metacognitive thinking from other kinds of thinking, it is necessary to consider the source of metacognitive thoughts: Metacognitive thoughts do not spring from a person's immediate external reality; rather, their source is tied to the person's own internal mental representations of that reality, which can include what one knows about that internal representation, how it works, and how one feels about it. Therefore, metacognition sometimes has been defined simply as thinking about thinking, cognition of cognition, or using Flavell's (1979) words, "knowledge and cognition about cognitive phenomena" (p. 906).

In Flavell's description quoted above, the idea that metamemory involves intelligent structuring and storage, intelligent search and retrieval, and intelligent monitoring suggests that metacognitive thoughts are deliberate, planful, intentional, goal-directed, and future-oriented mental behaviors that can be used to accomplish cognitive tasks (Flavell, 1971). Metacognition is an awareness of oneself as "an actor in his environment, that is, a heightened sense of the ego as an active, deliberate storer and retriever of information" (p. 275). It is the development of memory as "applied cognition" (p. 273), in which whatever "intellectual weaponry the individual has so far developed" is applied to mnemonic problems (Flavell, 1977, p. 191).

Often, further definition of a term can be gained by considering its source. Therefore, further definition of this fuzzy concept may be gained by considering a source of, or at least a likely contributor to, Flavell's idea of "knowledge and cognition about cognitive phenomena": Jean Piaget. Among the many notable accomplishments of Flavell is his work that introduced Piaget to many people in the United States. The Developmental Psychology of Jean Piaget (Flavell, 1963) has had tremendous impact on how researchers, practitioners, and the general public conceptualize child and adolescent cognitive development. And, even though recent advances in developmental psychology have indicated a need to modify some of Piaget's work, many of those advances in fact found their impetus in Piaget's theories.

The idea of deliberate, planful, and goal-directed thinking applied to one's thoughts to accomplish cognitive tasks is deeply embedded in Piaget's conceptualization of formal operations in which higher-ordered levels of thought operate on lower-ordered levels. During this stage of cognitive development, the abilities of the adolescent begin to differentiate from those of the child. Flavell (1963) wrote:

What is really achieved in the 7-11-year period is the organized cognition of concrete objects and events per se (i.e., putting them into classes, seriating them, setting them into correspondence, etc.). The adolescent performs these first-order operations, too, but he does something else besides, a necessary something which is precisely what renders his thought formal rather than concrete. He takes the results of these concrete operations, casts them in the form of propositions, and then proceeds to operate further upon them, i.e., make various kinds of logical connections between them (implications, conjunction, identity, disjunction, etc.). Formal operations, then, are really operations performed upon the results of prior (concrete) operations. Piaget has this propositions-about-propositions attribute in mind when he refers to formal operations as second-degree operations or operations to the second power. (p. 205-206, italics in original)

Inhelder and Piaget (1958) provided further elaboration on second-degree operations: "... this notion of second-degree operations also expresses the general characteristics of formal thought--it goes beyond the framework of transformations bearing directly on empirical reality (first degree operations) and subordinates it to a system of hypothetico-deductive operations--i.e., operations which are possible" (p. 254). Thus, first-degree operations, which are thoughts about an external empirical reality, can become the object of higher-order thoughts in an attempt to discover not necessarily what is real but what is possible. "Formal thinking is both thinking about thought... and a reversal of relations between what is real and what is possible" (p. 341-

342, italics added). Referring to Inhelder and Piaget's work, Flavell (1977) wrote: "Another way to conceptualize it is to say that formal operations constitute a kind of 'metathinking,' i.e., thinking about thinking itself rather than about objects of thinking. Children certainly are not wholly incapable of this and other forms of 'metacognition'" (p. 107).

Eight years after his call for metamemory research, Flavell (1979) acknowledged the wide interest and promise of this "new area of cognitive-developmental inquiry" (p. 906). At that time substantial work that would eventually be viewed as foundations of metacognitive research already had been accomplished by many others: Brown (1978), Belmont and Butterfield (1969), Corsini (1971), Hagen and Kingsley (1968), Hart (1965), and Markman (1977), to name only a few. And their areas of interest included such diverse topics as "oral communication of information, oral persuasion, oral comprehension, reading comprehension, writing, language acquisition, attention, memory, problem solving, social cognition, and various types of self-control, and self-instruction" (Flavell, 1979, p. 906). This work on metamemory added significantly to the information-processing paradigm that had emerged shortly before through the theorizing of researchers such as Newell, Shaw, and Simon (1958), Miller (1953), and Atkinson and Shiffrin (1968). Key to this new psychological paradigm was the conceptualization of thought as the flow of information in and out of a system of mental structures. Questions concerning how information is stored in and retrieved from those structures, how the structures develop with age, and how storage and retrieval are controlled drew the attention of many researchers.

Flavell's (1979) model of metacognition and cognitive monitoring developed from answers to many of those questions. According to his model, a person's ability to control "a wide variety of cognitive enterprises occurs through the actions and interactions among four classes of phenomena: (a) metacognitive knowledge, (b) metacognitive experiences, (c) goals (or tasks), and (d) actions (or strategies)" (p. 906). Metacognitive knowledge refers to one's stored world knowledge that "has to do with people as cognitive creatures and with their diverse cognitive tasks, goals, actions, and experiences" (p. 906). It consists of one's knowledge or beliefs about three general factors: his or her own nature or the nature of another as a cognitive processor; a task, its demands, and how those demands can be met under varying conditions; and strategies for accomplishing the task (i.e., cognitive strategies that are invoked to make progress toward goals, and metacognitive strategies that are invoked to monitor the progress of cognitive strategies). Metacognitive knowledge may influence the course of cognitive enterprises through a deliberate and conscious memory search or through nonconscious and automatic cognitive processes. Metacognitive knowledge may lead to a wide variety of metacognitive experiences, which Flavell describes as conscious cognitive or affective experiences that accompany and pertain to an intellectual enterprise.

A look at the aforementioned 12th-grade student will illustrate the components of Flavell's model of metacognition. The use of metacognitive knowledge can be inferred in at least three parts of the vignette. The first is when the student gains the metacognitive knowledge of how her knowledge of calculating the area of a rectangle can be used to obtain an approximation of the total area under the roller coaster by adding all the rectangular areas under the track. The use of metacognitive knowledge again can be inferred when she realizes that her memories of Disneyland, rather than being a distraction from the task, can be used to accomplish it: She has knowledge of the superstructure of the roller coaster at Disneyland, and she has metacognitive knowledge of how to use that knowledge to enhance the teacher's roller coaster analogy. The third illustration of metacognitive knowledge occurs near the end of the vignette when the student assesses her understanding of the lesson and realizes that she does not know the material well enough for the quiz. In this case, she has metacognitive knowledge of what she does not know.

Metacognitive experiences also are illustrated in three parts of the vignette. Once she understands how to use her knowledge of calculating the area of a rectangle to obtain an approximation of the total area, she has the metacognitive experience that there is something she still does not understand. What still eludes her is the understanding of how increasingly accurate approximations of the total area can be obtained with increasingly smaller widths of the rectangles. Another metacognitive experience occurs with the insight that her own personal experiences of the roller coaster at Disneyland can be used to enhance her understanding of the teacher's roller coaster analogy. Finally, when she hears about the quiz and assesses her lack of knowledge, the resulting metacognitive experience leaves her with the sinking feeling in her stomach that her grade for the course is going to suffer.

Strategy use is also illustrated in the vignette. In response to her metacognitive experience that she still does not understand how to obtain increasingly accurate approximations of the area, she increases her concentration on the teacher's explanation and on the diagram on the blackboard. Her use of this simple strategy may have been a nonconscious automatic response that she had acquired over years of learning, or it may have been the result of her conscious and deliberate choice. In the latter case, then, that choice likely required metacognitive knowledge of the task and of herself as a problem solver. Metacognitive knowledge of the task would be required to provide understanding of how she had previously managed the demands of tasks that she perceived to be similar to the one at hand; and metacognitive knowledge of herself would be required to provide understanding of whether she, as a problem solver, could meet those demands.

Unfortunately, her strategy immediately failed because of unforeseen environmental distractions and because the teacher's use of the roller coaster analogy created cognitive interference that further distracted her. In the face of these distractions, she continues to rely on her selected strategy and puts forth even more effort to concentrate on the task. Her strategy proves successful in filtering out the students' whispers, and it also leads to the insight about her memories of Disneyland. Once again, however, she is distracted from the task by the disturbing news of the quiz. Her metacognitive judgment that she has not learned the lesson fills her with dread of the outcome.

Thus, the vignette illustrates that metacognition involves "active monitoring and consequent regulation and orchestration" of cognitive processes to achieve cognitive goals (Flavell, 1976, p. 252). Monitoring, regulation, and orchestration can take the form of checking, planning, selecting, and inferring (Brown & Campione, 1980), self-interrogation and introspection (Brown, 1978), interpretation of ongoing experience (Flavell & Wellman, 1977), or simply making judgments about what one knows or does not know to accomplish a task. However, the vignette also illustrates that along with the ideas of "active" and "conscious" monitoring, regulation, and orchestration of thought processes is the possibility that thinking about one's thinking, through repeated use or overlearning, may become automatized and consequently nonconscious.

. . . conscious monitoring of mnemonic means, goals, and variables may actually diminish as effective storage and retrieval behaviors become progressively automatized and quasi-reflective through repeated use and overlearning. The metamemory-memory behavior link of the older child is not thereby extinguished, of course. However, the need for it to become clearly conscious may well diminish as the behaviors it once mediated become more self-starting. (Flavell & Wellman, 1977, pp. 28-29)

As was mentioned above, the 12th-grade student's use of the simple strategy to increase concentration may have been a conscious and deliberate choice, or it may have been a nonconscious automatic response developed over years of repeatedly attributing learning of difficult material to greater effort (e.g., Nicholls & Miller, 1984). If nonconscious and automatic, does her strategy use illustrate a metacognitive process or is it simply a cognitive one? At one time her response may have been conscious and deliberate. Should thoughts that were once metacognitive but have since become automatic through repeated use and overlearning still be called metacognitive? Automatic cognitive processes may involve knowledge and cognition about one's own cognitive phenomena just as metacognitive processes do.

However, because people are likely aware of only the products of nonconscious automatic processes and not the processes themselves, it is difficult if not impossible for people to report on them (cf. Ericsson & Simon, 1980), and accordingly, it is difficult if not impossible for researchers to know whether automatic cognitive processes reflect people's beliefs in what plausible links should exist between a stimulus and a response or of what links actually exist (Nisbett & Wilson, 1977). In their own right, beliefs in plausible links (i.e., a prior, causal theories, or on-line constructions) are deserving of study, but they likely do not reflect veridical reports of nonconscious cognitive processes. Without accurate reports to rely on, the study of nonconscious processes is greatly impeded.

Thus, whether the term metacognitive should be used to describe thoughts that were once metacognitive but have since become nonconscious and automatic remains a debatable issue. Certainly, the nonconscious and automatic nature of these thoughts contrasts sharply with other, more prominent, features of metacognition, namely, the extent to which metacognitive processes involve an awareness of oneself as "an actor in his environment" and a "deliberate storer and retriever of information." It seems reasonable, therefore, to adopt a convention that many researchers have (e.g., Borkowski & Muthukrishna, 1992; Bracewell, 1983; Carr, Alexander, & Folds-Bennett, 1994; Davidson, Deuser, & Sternberg, 1994; Paris & Winograd, 1990) and reserve the term "metacognitive" for conscious and deliberate thoughts that have as their object other thoughts. As conscious and deliberate, metacognitive thoughts are not only potentially controllable by the person experiencing them, but they are potentially reportable and therefore accessible to the researcher. This convention will be adopted throughout the remainder of this chapter.

Other Contributions to the Definition of Metacognition

Building on Flavell's contributions to metacognition, Kluwe (1982) brought further definition to the concept by identifying two general attributes common to "activities referred to as 'metacognitive': (a) the thinking subject has some knowledge about his own thinking and that of other persons; (b) the thinking subject may monitor and regulate the course of his own thinking, i.e., may act as the causal agent of his own thinking" (p. 202). Furthermore, using a distinction made earlier by Ryle (1949), Kluwe linked the first attribute to declarative knowledge, "stored data in long-term memory," and the second attribute to procedural knowledge, "stored processes of a system."

Importantly, Kluwe helped to make a finer distinction between what is and is not metacognitive -- something not always easily determined as was suggested by the earlier discussion of nonconscious and automatic thoughts. Stored data in long-term memory and stored processes of a system can be found at both metacognitive and cognitive levels. According to Kluwe, at cognitive levels, stored data may consist simply of domain knowledge, which refers to what a person knows about "domains of reality" (e.g., knowledge about mathematics, social interactions, personal history), and stored processes may consist simply of solution processes (i.e., processes directed to the solution of a specific problem). Portions of the twelfth-grade student vignette can be used to illustrate these ideas of non-metacognitive declarative and procedural knowledge. Non-metacognitive declarative knowledge is illustrated by the student's recollections of the textbook dealing with integration, the friend being discussed by her classmates, and last summer's vacation to Disneyland. These memories reflect stored data drawn from her mathematical knowledge and her personal knowledge domains. Non-metacognitive procedural knowledge is illustrated by the solution process to calculate the area of a rectangle. Likely, the student had long ago mastered this process, which she can now intentionally direct to the solution of a specific problem.

By contrast, processes that "monitor the selection and application as well as the effects of solution processes and regulate the stream of solution activity" represent, according to Kluwe (1982, p. 204) metacognitive procedural knowledge. Kluwe uses the term executive processes to denote this kind of procedural knowledge. Executive processes involve both monitoring and regulating other thought processes, and therefore, correspond with Flavell's (1979) metacognitive strategies and Brown's (1978) metacognitive skills. Executive monitoring processes are those that are "directed at the acquisition of information about the person's thinking processes" (Kluwe, 1982, p. 212). They involve one's decisions that help (a) to identify the task on which one is currently working, (b) to check on current progress of that work, (c) to evaluate that progress, and (d) to predict what the outcome of that progress will be. Executive regulation processes are those that are "directed at the regulation of the course of one's own thinking" (p. 212). They involve one's decisions that help (a) to allocate his or her resources to the current task, (b) to determine the order of steps to be taken to complete the task, and (c) to set the intensity or (d) the speed at which one should work the task. Thus, the general distinction between procedural and declarative knowledge and the finer distinctions between what is and is not metacognitive within each kind of knowledge have helped to further define metacognition and cognitive monitoring. But perhaps more importantly, Kluwe helped to emphasize the importance of metacognitive research as a way to gain greater understanding of humans not only as thinking organisms but as self-regulatory organisms who are capable of assessing themselves and others and directing their behavior toward specified goals.

It is important that human beings understand themselves as agents of their own thinking. Our thinking is not just happening, like a reflex; it is caused by the thinking person, it can be monitored and regulated deliberately, i.e., it is under the control of the thinking person. (Kluwe, 1982, p. 222)

Whether people can monitor and regulate their thinking, how and when they monitor and regulate, and whether greater chances for success are realized through monitoring and regulating depend on the task, the demands posed by the task, people's knowledge of the task, and the kinds of cognitive strategies they can bring to bear on the task. However, equally important is how people assess themselves as self-regulatory organisms, as "agents of their own thinking." For example, many people are convinced they are terrible at solving mathematical word problems, and because they assume that every mathematical word problem will forever evade them, they are little motivated to attempt a solution, and even less motivated to monitor and regulate their attempts. Also, many people are overwhelmed by stress and anxiety whenever they are asked to perform in front of a group of peers thereby making it nearly impossible for them to monitor and regulate their performance. Thus, self-assessments of one's affective states often serve as the gateway to further assessments concerning the task, its demands, the knowledge necessary for its completion, and strategies for its completion. These personal-motivational states often "determine the course of new strategy acquisition and, more importantly, the likelihood of strategy transfer and the quality of self-understanding about the nature and function of mental processes" (Borkowski, Carr, Rellinger, & Pressley, 1990, p. 54).

The notion of self-efficacy is echoed by Paris and Winograd (1990) who believe that most researchers now recognize a definition of metacognition that "captures two essential features of metacognition -- self-appraisal and self-management of cognition" (p. 17). Self-appraisals are people's personal reflections about their knowledge states and abilities, and their affective states concerning their knowledge, abilities, motivation, and characteristics as learners. Such reflections answer questions about "what you know, how you think, and when and why to apply knowledge or strategies" (Paris & Winograd, 1990, p. 17, italics in original). Self-management refers to "metacognitions in action," that is, mental processes that help to "orchestrate aspects of problem solving" (p. 18). Focusing on self-appraisal and self-management helps in the conceptualization of learners as individuals who need to be actively involved in the orchestration of their knowledge construction.

In summary, this brief examination of the definition of metacognition was intended to provide an overall view of the kinds of thought processes that have been associated with it. Certainly, much more could be said about the characteristics and dynamics of metacognitive processes. Hopefully, this cursory synthesis of the literature has shown that what started out in the 1970s as a "fuzzy" concept embedded within developmental research has evolved over 25 years into a more precisely defined concept that can be found in many areas of psychological research. Although not all researchers will agree on some of the fuzzier aspects of metacognition, there does seem to be general consensus that a definition of metacognition should include at least these notions: knowledge of one's knowledge, processes, and cognitive and affective states; and the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states.

Metacognitive Research

Now that a definition of metacognition has been attempted, what will likely resolve even more of the fuzziness surrounding the concept is to move beyond the question of what it is and address the question of how has it been studied. Adopting a constructivist point of view, which is so prevalent in education today, one can argue that the realities we come to know reflect the ways in which we come to know them. Glasersfeld (1984) has provided further elaboration of this argument, "the experiencing consciousness creates structure in the flow of its experience; and this structure is what conscious cognitive organisms experience as 'reality'" (p. 38). Therefore, the knowledge that researchers have gained of metacognition can be further illuminated by looking at the ways in which they have gained it.

Most of the early investigations of metacognition were descriptive in nature in that they sought to describe general developmental patterns of children's knowledge about memory processes, particularly processes concerned with conscious and deliberate storage and retrieval of information. However, as studies moved from descriptive to empirical, the kinds of methodology expanded, the number of studies ballooned, and the need for a scheme to classify this growing corpus of literature on metacognition arose. Several classification schemes have been used to group, analyze, and evaluate these studies (e.g., Cavanaugh & Perlmutter, 1982; Kluwe, 1982; Schoenfeld, 1987; Schneider, 1985), and even though there are important differences among them, overall, three general categories consistently appear.

The first category includes studies of cognitive monitoring. These studies have examined people's knowledge of their knowledge and thought processes and how accurately they can monitor the current state of their knowledge and processes (Kluwe, 1982; Schoenfeld, 1987). Many of these studies assess prediction performance (i.e., predictions of what knowledge is stored in memory) and effort and attention allocation (i.e., allocation of study based on one's judgments about knowledge that is or is not currently in memory) (Schneider, 1985). Often, subjects' verbal reports during the performance of a memory task are used to determine what memory knowledge the individual brings to the task (Cavanaugh & Perlmutter, 1982).

The second category includes studies that have examined "regulation of one's own thinking processes in order to cope with changing situational demands" (Kluwe, 1982, p. 210). These studies typically include both a training task and a strategy transfer task (Schneider, 1985). First, people are taught a strategy to complete a specific task. Once they have demonstrated mastery of the strategy, they are given another task (i.e., the transfer task), different from the first but structurally equivalent to it. People then must decide whether to use the instructed strategy, modify it, or abandon it in favor of a different strategy that could be used to complete the transfer task.

Finally, the third category includes studies in which both monitoring and regulation are examined. In these studies, people monitor available information during the course of their own thinking and then use this information to regulate subsequent memory processes (Kluwe, 1982; Schoenfeld, 1987; Schneider, 1985). Often, these studies focus on people's organizational or elaboration strategies in memory and how strategies can be used to improve performance (Schneider, 1985). A goal of these studies is to discover what and how much people know about memory that is relevant to performance of a particular memory task (Cavanaugh & Perlmutter, 1982).

Studies of Cognitive Monitoring

Ability to monitor one's knowledge and processes is no trivial matter as far as education is concerned. Currently, educators have great interest in self-regulation of learning. "Theoreticians seem unanimous--the most effective learners are self-regulating" (Butler & Winne, 1995, p. 245). Key to effective self-regulation is accurate self-assessment of what is known or not known (Schoenfeld, 1987). Only when students know the state of their own knowledge can they effectively self-direct learning to the unknown. Therefore, knowing whether students can accurately monitor their knowledge and thought processes and whether memory monitoring of complex tasks can be taught to younger children are key concerns of teachers, researchers, and theoreticians interested in encouraging self-regulation of learning.

"Tip-of-the-tongue" experiences, feeling-of-knowing (FOK) judgments, serial recall, allocation of study effort, "seen" judgments, judgments of learning (JOL), and ease-of-learning (EOL) judgments are all metacognitive phenomena that have been used to investigate the notion that people have knowledge of their knowledge and thought processes and can accurately monitor their knowledge and processes. Tip-of-the-tongue experiences, the investigation of which can be traced back to William James (1890), concern a person's judgment that currently forgotten information is in fact recallable, that is, the memory is on the tip of one's tongue. Closely related, FOK judgments concern a person's knowledge that a currently forgotten or unrecallable item can be recognized when presented with other items. Serial recall has been used to determine how accurately people can judge whether a sequence of pictures or words they have seen for a brief period can be recalled. Allocation of study has been used to examine how accurately people can judge the current state of their knowledge, and based on that judgment, whether they allocate greater effort to study items that have not yet been learned. Seen judgments concern a person's knowledge of whether an item has been seen before; JOLs concern a person's knowledge of whether an item has been learned; and EOLs are judgments about how difficult it will be to learn new information from a particular domain given what one knows about that domain. Four of these metacognitive phenomena (FOK, serial recall, allocation of study effort, and JOLs) will serve here as illustrations of this category of metacognitive research.

Remarkably, as far back as the mid-60s, during the early years of the cognitive revolution, Hart (1965) investigated people's accuracy in monitoring their stored knowledge. Using what has become known as the recall-judgment-recognition (RJR) paradigm, the dominant research paradigm for feeling-of-knowing judgments, Hart first asked undergraduate students to recall answers to a collection of general-information questions that were drawn from a variety of subject areas. Using only those items that students had gotten wrong, Hart then asked them to make FOK judgments about whether they would be able to recognize the correct answers to the questions from among several wrong answers. Finally, students were given a multiple-choice test and asked to recognize each correct answer. Thus, students' accuracy in monitoring their knowledge could be determined by comparing their FOK judgments with their actual recognition performance. Hart found that feeling-of-knowing judgments for the undergraduate students were relatively accurate indicators of what is or is not stored in memory. However, similar investigations that used young children (e.g., Wellman, 1977) have shown that feeling-of-knowing judgments are much less accurate. Although evidence has not always been consistent (see Butterfield, Nelson, & Peck, 1988, for a surprising reversal of these results), overall, studies examining FOK have shown a developmental pattern: With increasing age, knowledge about what is or is not stored in memory becomes increasingly accurate.

Using serial recall, Flavell, Freidrichs, and Hoyt (1970) showed young children (i.e., preschoolers to fourth graders) for very brief times successively longer sequences of pictures of familiar objects. The researchers then asked the children to predict whether they could recall the pictures in correct serial order, after which the children were asked to recall them. The children's predicted recall compared with actual recall indicated that the youngest children tended to overestimate their recall ability, whereas the older children not only could hold more pictures in memory than the younger children, but they were more accurate in their predicted recall.

Bisanz, Vesonder, and Voss (1978) showed that there are developmental differences between young (i.e., first and third grade students) and older children (i.e., fifth graders and college students) in the ability to monitor current knowledge in memory and in how the results of monitoring are used in the allocation of study effort. These authors first asked students to learn lists of picture pairs. Knowledge of the picture pairs was tested by presenting students one of the pictures from each pair to serve as a cued recall for the second picture. After all of the picture pairs were tested, students were told that they were going to learn all of the picture pairs until they got them all right. They were again presented with each of the picture pairs and asked to answer whether they had gotten each correct. They were then encouraged to try to remember each. After all the picture pairs had been restudied, students were retested. This procedure was followed until each student reached a criterion. Results showed that discrimination between correct and incorrect items was accurate for all grades, although first grade subjects made more false positives (i.e., said they had gotten a pair correct when in fact they had not) than older subjects. In addition, older students utilized their on-going monitoring judgments by allocating greater study to those items they had reported as incorrect, whereas younger students were less inclined to do so. Thus, students at all four grades could monitor current knowledge and processes in memory, but monitoring ability increased with age. Moreover, older students were more inclined than younger students to use memory monitoring information to allocate greater study to those items they had monitored as incorrect.

In the last study to be discussed, Nelson and Dunlosky (1991) used judgments of learning (JOLs) to investigate whether accuracy of memory monitoring of recently learned knowledge was affected by the amount of time that was allowed to transpire between learning and monitoring. A JOL is made after a person has studied an item; it reflects the person's confidence that a recently studied item will be remembered on a future test. Nelson and Dunlosky hypothesized that if a memory-monitoring judgment is made immediately after an item has been learned, there is a possibility that what the person is monitoring is short-term memory rather than long-term memory. Because future test performance depends on knowledge in long-term memory, a JOL based predominantly on knowledge in short-term memory will be of little predictive value. To test their hypothesis, these researchers asked college students to make JOLs either immediately after learning an item or after a filled delay. They found that JOLs made after a delay were dramatically more accurate than JOLs made immediately or shortly after learning. Thus, in determining whether people can accurately monitor their memories, it is important to consider whether it is long- or short-term memory that is being monitored. Long-term predictions of future test performance based on monitoring of short-term memory are likely to be inaccurate.

Overall, research from the first category of metacognitive research has shown that even kindergartners can accurately monitor their knowledge. With increase in age, however, people gain not only in the amount of knowledge that can be held in memory, but they gain in how accurately they can monitor their knowledge. Although in judging memory monitoring ability, it is important to consider more than simply age. One must consider the kinds of thought processes or knowledge that are being monitored. When memory monitoring tasks are simple and do not overload working memory (e.g., simple recall or recognition tasks) there is little difference between younger and older children (Schneider, 1985). But as the complexity of tasks increases, such as using strategies to allocate greater study time to more difficult items, so does the difficulty in monitoring the thought processes necessary to complete them (Schneider, 1985).

Studies of Cognitive Regulation

The second category of metacognitive research includes studies that have examined "regulation of one's own thinking processes in order to cope with changing situational demands" (Kluwe, 1982, p. 210). Many of the earliest studies from this category were focused on mentally or educably retarded children (e.g., Brown & Campione, 1977; Butterfield & Belmont, 1980); however, more recently, children representative of a broad spectrum of abilities have been used. Typically, these studies include both a training task and a strategy transfer task (i.e., a task different from the training task but structurally equivalent to it). People are first taught a strategy to complete a task. Tasks have included sort-recall, free recall, alphabet search, word or picture association, or letter-series completion. Once mastery of the strategy has been demonstrated with the training tasks, a transfer task is given to determine whether people use the strategy, modify it, or abandon it in favor of a different one. Thus, as people learn a strategy to facilitate performance on the training tasks, researchers examine whether they develop metacognitive awareness of the utility and function of the strategy, which is essential if people are to regulate application and modification of strategies to meet new situational demands.

A study illustrative of the second category of metacognitive research is Lodico, Ghatala, Levin, Pressley, and Bell (1983). The purpose of this study was to determine whether instruction of general principles of strategy monitoring would influence children's regulation of strategies on subsequent tasks. Earlier research had shown that it is difficult to teach children to continue to use instructed strategies when presented with new tasks, even if the tasks could be efficiently accomplished by using the strategies. Lodico et al. (1983) hypothesized that for children to maintain the use of a strategy on their own, it is necessary for them to learn the value of the strategy for improving their performance. Furthermore, these researchers hypothesized that children can learn the value of a strategy through training that focuses on monitoring the relationship between strategic behavior and task performance.

Seventy-two second-grade students were assigned to one of two training conditions. In one condition, students were trained to monitor the effectiveness of two strategies designed to help draw a circle and two strategies for remembering a list of letters. In the other condition, students were exposed to the same strategies, however, they received no monitoring training. Subsequently, half of the students in each condition were taught two strategies for learning a paired-associate word task, one strategy being more effective than the other; the other students were taught two different strategies for a free-recall word task, also with one strategy being more effective than the other. After practicing, all children were asked to assess their performance with the two strategies and to explain any differences between the two. They were then given another trial with the task, but this time they could choose the strategy they believed was more effective. After completing the task, they were asked why they had chosen the one strategy that they had.

Results showed that a greater proportion of the children who were taught to monitor strategy effectiveness than of those who were not so trained (a) recognized that their better performance on the task was due to the more effective strategy, (b) choose the more effective strategy when given a choice, and (c) explained that their choice was made because they believed it would improve their performance. In contrast, a majority of the children who did not receive monitoring training either could not explain why they had chosen a particular strategy or their explanations were unrelated to performance. Thus, this study joins with others (e.g., Butterfield & Ferretti, 1987; Cavanaugh & Borkowski, 1979; Moynahan, 1978) in showing that young children can be trained to monitor their strategic behavior and performance and that this training can enhance their regulation of efficient strategies. Moreover, if people are taught metacognitive awareness concerning the utility and function of a strategy as they are taught the strategy, they are more likely to generalize the strategy to new situations.

Studies of Cognitive Monitoring and Regulation

Finally, the third category of metacognitive research includes studies in which people monitor available information during the course of their own thinking and then use this information to regulate subsequent memory processes (Kluwe, 1982; Schneider, 1985; Schoenfeld, 1987). Paris and Winograd (1990) likely would refer to this category of research as studies of self-management, that is, "metacognitions in action" that help to "orchestrate aspects of problem solving" including "the plans that learners make before tackling a task," "the adjustments they make as they work," and "the revisions they make afterwards" (p. 18). According to Kluwe (1982), these studies, along with studies from the second category, show what "is at the core of metacognition" (p. 211).

Many of the studies from this category have employed a sort-recall paradigm in which people are asked to recall as many of the words or pictures as possible that appear on provided lists (Schneider, 1985). The task requires that people (a) monitor their processing of the lists of words or pictures, (b) understand that recall can be facilitated by strategically sorting the words or pictures according to meaningful categories, and (c) regulate their recall by using the categories as memory prompts. In some of these studies, students have been instructed to use strategies to facilitate recall; in others, students have been observed for spontaneous use of strategies. Salience of the relationships among items to be recalled has been manipulated as well as the salience of the relationships between the kinds of items and students' base knowledge. In some studies, metacognitive monitoring and regulation has been inferred only if people can verbalize how their recall was facilitated by using a sorting strategy.

Corsale and Ornstein (1980) provide an example of this category of metacognitive research. Third- and seventh-grade students were assigned to one of three conditions, each condition receiving different instructions concerning a sorting task that used semantically unrelated pictures. Students in one condition were instructed to sort pictures into groups that "go together," however, they were not told that they would need to subsequently recall the pictures; students in a second condition were instructed to sort the pictures so that they would be able to recall them at a later time; and students in the third condition received a combination of the instructions given to the other two conditions. Results showed that for seventh-grade students there were no differences among the three conditions in the amount of recall. Apparently, even the seventh-graders who were not forewarned of the recall task were able to use organizational strategies to facilitate recall on a par with those students who had been forewarned. Surprisingly, third-grade students who were told to sort the pictures for later recall performed worse than third graders in the other two conditions. Even though these younger students later indicated that they knew a sorting strategy would help their recall, being forewarned of future recall did not help them develop such a strategy. Their production deficiency could be explained by a lack of knowledge concerning the kind of strategy to use with unrelated items or when a strategy should be used. But, for whatever reason, by the time students reach seventh grade, knowledge of strategy production and use appears to develop.

In general, studies that have used the sort-recall paradigm have shown that even 6-to-8 year old children can monitor incoming information necessary to perform recall tasks and can understand that recall is facilitated by strategically sorting information into meaningful categories. However, young children appear to have difficulties spontaneously regulating recall either because they lack knowledge of appropriate sorting strategies, or they know appropriate strategies but lack knowledge of when the strategies should be used, or they are uncertain about the importance of the strategies. Often, young children will rely on less effective, although familiar, rehearsal strategies even when more effective strategies have been demonstrated to them. But, by the age of 10 years, children begin to spontaneously use sorting strategies to facilitate recall. Although even at this age, ability to use sorting strategies may depend on whether the child has sufficient knowledge relevant to the items being recalled (Schneider, 1985).

Other studies from the third category of metacognitive research have examined how people regulate their selection of strategies based on information they monitor while employing the strategies. People are assumed to have monitored and regulated their use of strategies if, after using the strategies, they select the more or most efficacious one. This kind of study is illustrated by Pressley, Levin, and Ghatala (1984) in which students first were taught to use sentence-elaboration and repetition strategies to learn vocabulary words. After the two strategies were learned, students were asked to choose the more effective strategy to learn a list of new vocabulary words, but before choosing, they were assigned either to a no-practice or a practice condition. In the former, students were not allowed to practice the strategies prior to choosing one; in the latter, students were allowed to practice using a long vocabulary list. Students in both conditions were further assigned to one of three recommendation conditions: Before students made their choice of a strategy, the experimenter recommended either the sentence-elaboration or repetition strategy, or gave no recommendation. Results showed that in the absence of practice, students were more likely to choose the strategy that was recommended by the experimenter. However, after practice and testing, students were more likely to choose the more effective strategy, the elaboration strategy, despite the experimenter's recommendation. Thus, by monitoring their practice and testing of the two strategies, students gained an awareness of the relative effectiveness of the two and regulated subsequent strategy use by choosing the one that had been shown to be more efficacious, even if the experimenter had made a recommendation to the contrary.

Studies Examining Metacognition in Education

More recently, a fourth category of metacognitive research has appeared. The strong focus on theoretical aspects of metacognition, which has dominated much of the metacognitive research since the 1960s, lately has produced an equally strong focus on educational application. Many researchers, convinced of the educational relevance that metacognitive theory has for teachers and students, are shifting their attention from the theoretical to the practical, from the laboratory to the classroom. For example, Borkowski and Muthukrishna (1992) argue that metacognitive theory has "considerable potential for aiding teachers as they strive to construct classroom environments that focus on strategic learning that is both flexible and creative" (p. 479); and Paris and Winograd (1990) argue that "students can enhance their learning by becoming aware of their own thinking as they read, write, and solve problems in school. Teachers can promote this awareness directly by informing students about effective problem-solving strategies and discussing cognitive and motivational characteristics of thinking" (p. 15).

Therefore, this fourth category of metacognitive research includes studies that have examined ways in which metacognitive theory can be applied to education. Broadly defined, these studies have focused on a fundamental question, Can instruction of metacognitive processes facilitate learning? The researchers who have contributed to the present volume, along with many other researchers and educational practitioners, have responded to this question with a resounding YES. The present volume contains many examples of the ways in which researchers have provided answers to this question in specific educationally relevant domains: Davidson and Sternberg have provided answers in the domain of general problem solving; Dominowski in the domain of verbalization of cognitive processes; Vye, Schwartz, Bransford, Barron, Zech, and The Cognition and Technology Group at Vanderbilt in the domain of science; Carr and Biddlecomb in the domain of mathematics; Sitko in the domain of writing; both Otero and Hacker in the domain of reading; García, Jiménez, and Pearson in the domain of bilingual education; Maki in the domain of test prediction; Winne and Hadwin in the domain of studying; Pressley, Van Etten, Yokio, Freebern, and Van Meter in the domain of academic coping; McGlynn in the domain of rehabilitation; and Dunlosky and Hertzog in the domain of aging and problem solving.

These researchers would likely agree that to enhance learning to the fullest, learners need to become aware of themselves as self-regulatory organisms who can consciously and deliberately achieve specific goals (Kluwe, 1982). In general, metacognitive theory focuses on (a) the role of awareness and executive management of one's thinking, (b) individual differences in self-appraisal and management of cognitive development and learning, (c) knowledge and executive abilities that develop through experience, and (d) constructive and strategic thinking (Paris & Winograd, 1990). Thus, the promise of metacognitive theory is that it focuses precisely on those characteristics of thinking that can contribute to students' awareness and understanding of being self-regulatory organisms, that is, of being agents of their own thinking.

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1 Typically, a distinction is made between metamemory and metacognition. Often, metamemory is defined as knowledge about memory and memory processes, and metacognition is defined as knowledge of cognition and monitoring and control of cognitive activities. If one does not closely scrutinize the definition of memory, this distinction can be maintained. However, if one accepts a definition of memory as "applied cognition" (Flavell, 1971, p. 273), the distinction becomes considerably blurred. In which case, the definition of metamemory becomes, knowledge about applied cognition, which appears to be simply metacognition. To further blur the distinction between the two terms, Flavell (1977) describes as part of metamemory, knowledge of the variables that interact to affect memory performance. These variables include person, task, and strategies. The person variable includes knowledge of oneself and others as storers and retrievers of information and the ability to monitor and interpret one's memory in specific memory situations. Once again, what is defined as metamemory seems considerably blurred with what is defined as metacognition. Thus, the convention adopted for this chapter is that metamemory is not distinct from metacognition; rather, it is a case of metacognition in which the object of thought is memory.

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