NEUROPSYCHOLOGY AND COGNITION

Metacognition in Learning and Instruction

Theory, Research and Practice

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CHAPTER 3

DEVELOPING STUDENTS' METACOGNITIVE KNOWLEDGE AND SKILLS

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ABSTRACT. Recent research highlights the importance of both metacognitive knowledge and metacognitive skills in learning. This chapter reviews some of the recent literature on metacognition in learning and describe some methods of helping students acquire strategic metacognitive knowledge and executive management metacognitive skills to improve their learning. Topics focused on include reading metacognition, graphic organizers, self-assessment, self-questioning, and thinking aloud, all of which can be used across content domains.

This chapter discusses research on metacognition in learning and tutoring and describes ways to help students develop and apply metacognitive knowledge and strategies. In this chapter, a strategy is defined as a conscious, deliberate use of a specific method, whereas a skill is defined as a refined strategy which is used selectively, automatically and unconsciously as needed. From an information processing perspective, metacognitive, executive control processes , which guide the flow of information through the mind and regulate cognition, explain why some students learn and remember more than others (Woolfolk, 1998). High achieving students have been found to possess more metacognitive awareness and engage in more self-regulatory behavior than low achieving students. Indeed, metacognition in general has been found to be an important characteristic of expertise (Meichenbaum & Biemiller, 1998; see Sternberg, Chapter 12). The kinds of metacognition discussed in this chapter can "make or break" academic success; they are the kinds of knowledge and strategies that successful people tend to figure out for themselves and that some people must be taught. When used extensively and in varied contexts, metacognitive knowledge and strategies can be used automatically in skilled performance.

Use of metacognition has been demonstrated to be essential to learning. General strategic, metacognitive knowledge and strategies, and domain-specific knowledge have been shown to have important roles in thinking and problem

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solving (Bransford, Sherwood, Vye and Rieser (1986). Extensive research and the componential subtheory of Sternberg's triarchic theory of intelligence suggest that high-achieving students are more metacognitive than low-achieving students (Sternberg, 1985). Zimmerman (1990) characterizes the metacognitive processes of self-regulated learners in terms of planning, setting goals, organizing, self-monitoring and self-evaluating at various times during the learning process. Zimmerman (1995) points out that it is not enough for students to have metacognitive knowledge (or skills); they also must self-regulate its use when confronted with stress, competing attractions and fatigue. Context-dependent motivational issues, such as effort, self-efficacy, persistence and task choice are also important determinants of self-regulation. Metacognition is necessary, but not sufficient, for academic success.

Research on learning emphasizes the importance of attention to higher level thinking (including problem solving, metacognition, and critical thinking) and affect (including motivation, self-concept, affective self-regulation and attributions) in addition to the traditional focus on content and basic skills. Learning is best when it is active, meaningful, retained over time, and transfers to a variety of contexts. A vitally important but often neglected aspect of learning is that often students have the requisite knowledge and skills for performing complex tasks but do not use them; i.e, the skills remain inert. Sometimes this is because students are not motivated or confident to apply them, and sometimes students simply do not recognize that the situation calls for use of particular knowledge and skills. That is, students may have declarative and procedural knowledge, but not the contextual or conditional knowledge needed for application and transfer (Hartman & Sternberg, 1993). Garner's (1990) theory of settings suggests that the nature of strategic activity often varies with the context. She notes that children and adults often fail to use the strategies at their disposal because minimal transfer, attributions and classroom goals do not support strategy use, the knowledge base is not adequately developed, and learners tend to use primitive routines and show poor cognitive monitoring. According to Garner's theory of settings there are at least six contextual factors that affect strategy use. These factors include strategies being too tightly linked to particular situations, lack of knowledge about the relationship between strategy use and task demands, and classroom settings that do not value the effortful application of strategies.

Although over the past two decades research has documented the important role of metacognition in learning, many students are unaware of the concept of metacognition and do not reflect on their thinking and learning strategies and attitudes and how they might be improved. Knowing about your own knowing or thinking about your own thinking - metacognition- includes thinking about your own thinking *processes* and the *products* of your thinking. Two fundamental aspects of metacognition are *awareness* of and *control* over one's thinking. Two basic types of metacognition are *executive management* strategies for planning,

monitoring, evaluating and revising one's thinking processes and products, and *strategic knowledge* about what information and strategies/skills one has (declarative), when and why to use them (contextual/conditional), and how to use them (procedural). Some metacognition is domain-general, applying across subjects and situations; and some is domain-specific, applying selectively to particular subjects and situations (see Schraw, Chapter 1 and Wolters & Pintrich, Chapter 6). Research suggests that the development of metacognition begins by five to seven years of age and is enhanced during and through schooling (Flavell, 1985; Flavell, Green, & Flavell, 1995; Garner, 1990).

Cognitive (worker) skills perform the intellectual work decided on by the metacognitive bosses. Examples of cognitive skills include encoding (registering information), inferring, comparing, and analyzing. Metacognition refers to "thinking about thinking, " such as deciding how to approach a task. Metacognitive (boss) skills involve executive management processes such as planning, monitoring and evaluating. Although cognitive skills are important, Wagner and Sternberg (1984) argue that teaching needs to emphasize metacognitive skills because:

1. Teaching specific strategies, such as the order in which to perform a particular task, will not give students the skills they need in the long run. Students must learn general principles such as planning, and how to apply them over a wide variety of tasks and domains.
2. Both the long-term benefits of training in cognitive skills and the ability to apply cognitive skills to new tasks appear to depend, at least in part, on training at the metacognitive level as well as at the cognitive level. Metacognitive knowledge and skills are needed for effective cognitive performance.
3. Generally students have a history of blindly following instructions. They have not acquired the habit of questioning themselves to lead to effective performance on intellectual tasks.
4. Students with the greatest metacognitive skill deficiencies seem to have no idea what they are doing when performing a task.
5. Students have metacognitive performance problems of: a) determining the difficulty of a task; b) monitoring their comprehension effectively, i.e. they don't recognize when they don't fully understand something (e.g. task directions, information in textbooks); c) planning ahead (e.g. what they need to do and how long each part should take); d) monitoring the success of their performance or determining when they have studied enough to master the material to be learned; e) using all relevant information; f) using a systematic step-by-step approach; g) jumping to conclusions; and h) using inadequate or incorrect representations.
6. Metacognitive skills and knowledge, as important as they are, are not often taught in most areas of the curriculum.

SELF-ASSESSMENT

Because mastery of course content is often assessed by students' performance on multiple-choice tests, students' ability to assess whether they have selected the right answer may help students attain the goal of earning the best grade possible. Self-regulating students engage in learning activities with specific goals in mind, observe their performance as they work, evaluate progress in attaining their goals and react by continuing or changing their approach as needed, depending upon the value of the task and upon perceived self-efficacy (Schunk 1991). Students who observe and evaluate their performance accurately may react appropriately by keeping and/or changing their study strategies to achieve the goal of maximizing their grade in a course or on a test. In order to study students' evaluation of their academic performance students were given a group-administered metacognitive assessment procedure (Hartman, 1995). Students were 49 freshmen taking a required course in World Arts at a large, urban, ethnically diverse university. High-achieving students were expected to show better metacognition, defined as accurate final grade predictions, than low-achieving students. Moreover, prediction inaccuracy, defined as the difference between predicted and actual grades, was expected to be negatively related to final grades. The results supported the expected relationship between achievement and metacognition; both the predicted grades and the prediction difference correlated significantly with final grades.

A related study by Prohaska (1994) found that at the beginning of the semester, high-GPA students made more accurate predictions of their grades in psychology than low-GPA students. Low-achieving students overestimated their grades more than high-achieving students. High GPA students were more confident about their grade estimates than were low GPA students. Other research showed that both low- and medium-ability students overestimated virtually all of their grades with confidence (Prohaska & Maraj, 1995).

The results suggest that many students could benefit from improved awareness of factors affecting their grades and strategies they can use to get better grades, so that as self-directed learners they can make appropriate efforts to attain the grade goals they have set for themselves. (See the error analysis and question analysis methods discussed later in this chapter as examples.)

CULTURAL INFLUENCES

Research demonstrates cultural and social influences on students' self-perceptions. For example, self-concept is affected by factors including social influences, such as peers and significant others; physical considerations, such as physical appearance and ability; and gender (Shavelson & Bolus, 1982; Skaalvik

& Rankin 1990). In a study of predictors of college graduation, Tracey & Sedlacek (1987) found a differential impact of academic self-concept as a function of ethnicity. Although it was a useful predictor of success for white students, it was not useful for black students. Research suggests there are ethnic differences in locus of control (Kumea-Shorter, 1976 ; Lao, Chuang, & Yang, 1977; & Cole, Rodriguez and Cole, 1978). Mestre (1989) cites research identifying cultural factors that affect mathematics learning. He believes comprehensive attempts to improve math education for minorities must take into account cultural, linguistic, socioeconomic, and attitudinal factors. Cognitive style research has demonstrated that variations within ethnic groups are generally greater than variations among them. Various cultures tend to show considerable similarities in their cognitive styles. (Shipman & Shipman, 1985).

According to Anderson (1988), most minority college students are inadequately prepared to compete with better educated, more affluent students. Unfortunately, most colleges respond by retention programs than emphasize only remediation and counseling. These programs have not been very successful with ethnic minorities in part because of the ethnocentric assumption that minorities have the same cognitive framework as whites. Anderson believes this assumption leads retention program developers to base their approaches on learning theories derived from Anglo-European views about learning, achievement, and cognitive functioning. These programs rarely attempt to identify the learning preferences and cognitive assets of non-white students. Minority students are expected to adapt to the instructional program rather than the instructional program adapt to meet students' needs. The culture of the classroom may conflict with students' cultural styles. For example, while college classrooms often emphasize competition and individual achievement, students from non-western cultures may be more accustomed to group cooperation and value group achievement. Often minority student differences are equated with deficiencies.

How do students from different ethnic backgrounds compare and contrast on metacognitive variables that affect academic performance? The BACEIS model (described in the Preface and later in this chapter) suggests that there may be cultural differences in metacognition and the relationship between metacognition and other variables that affect academic performance. Supporting these predictions is research suggesting that problem-solving metacognition is related to students' academic self-concepts, and that culturally distinct ethnic groups vary on these measures and their interactions (Hartman, Everson, Tobias & Gourgey, 1996). Analysis of variance showed there were significant main effects due to ethnicity in self-reports of metacognition; black students reported the most use, Asian students reported the least use, and Hispanic students were in the middle. There was also a significant interaction between gender and ethnicity in metacognition. Black females reported more use of metacognition than black men, while Asian and

Hispanic men reported more use of metacognition than women in their respective groups. The finding regarding Asian students' reports of relatively little use of metacognition may be a reflection the Asian practice of self-criticism.

The cultural background of students and teachers appears to have a variety of effects on academics. Cognitive developmental theories describe cultural acquisitions as cognitions that develop in people because the society requires or emphasizes them. For non-native speakers of English, linguistic diversity may affect students' academic performance as well as teachers' attitudes and expectations. Cultural factors, such as ethnic or gender stereotypes, may also trigger certain teaching behaviors, such as lowering standards or expectations, thereby affecting the quality of instruction, and in turn academic achievement.

Upon awareness of the high failure rate of black students in freshman calculus, Treisman (1985) examined the academic behavior of black and Chinese students and found that black students, unlike Chinese, rarely studied with classmates. Chinese students often worked in informal study groups. Cooperative work with a shared purpose, which research suggests creates an environment rich in metacognitive processing, enables Asians to share their mathematical knowledge, check out their understanding and approaches, and critique each other. Consequently, cooperative learning facilitates both content acquisition and metacognition. Additionally, while black students worked approximately eight hours a week on math, Chinese students worked around fourteen hours per week on the same tasks. Finally, black students rarely utilized the free tutoring provided on campus because they viewed themselves as self-reliant, which was one of their greatest strengths before college. Treisman used these findings to design an academic support Workshop program in which black students worked collaboratively on difficult problem sets for six to eight hours per week. He found that black Workshop participants, on average, consistently earned one full grade higher than black students who did not participate in the workshops. Retention was also improved. Workshop participants' persistence rate was 76% after the first two years in college, while the persistence rate of non-Workshop participants was 57%. The results suggest that metacognitive strategies of students from one cultural background may have benefitted students from a different cultural background, thus cultural practices may influence metacognitive learning.

Cultural variables, such as those observed by Treisman, can affect thinking and learning. Another major cultural factor that impacts education is when the students' native language is different from the language of instruction, which can affect students' ability to acquire knowledge through reading, as well and their ability to communicate what they have learned through writing.

METACOGNITIVE READING STRATEGIES

When sitting at home reading an assignment in history, science, or English, to what extent do students understand what they read in their texts? As they progress from one course or grade level to the next, to what extent do they have the reading abilities that their instructors generally assume?

Alexander's (1995) Domain Model of Learning suggests self-regulation, such as metacognition, is affected by the level of one's knowledge in a particular domain. Novice learners are likely to engage in metacognitive activities less often and less successfully than learners with more subject area knowledge, who are at the competence stage of learning in a domain. What are the implications for students who must learn the subject area by reading about it in a language different from their native tongue? Some students will compound lack of prior knowledge in a subject with minimal knowledge of the language in which it is written. To what extent does the use of successful metacognitive reading strategies transfer across languages?

Baker (1989) reviewed some recent studies with adult readers. She found that in general, good readers, who are good students, appear to have more awareness and control over their own cognitive activities while reading than do poor readers. In her characterization of the "expert reader", Baker noted that research on metacognitive strategies shows that they interact with domain-specific knowledge. For example, experts and novices in specific domains differ in how they budget and regulate their reading time. Domain-knowledge sometimes includes metacognitive knowledge of the relative effectiveness of various strategies. Studies comparing good and poor readers identify a variety of metacognitive skills that enhance reading comprehension. According to Brown (1980) and others, good readers regularly plan, attend to task demands, predict, use strategies to increase their comprehension and meet task requirements, check, monitor, reality test, control and coordinate their learning. Four effective reading comprehension strategies found by Jones, Amiran and Katims (1985) were: organizational, contextual and reflective thinking, and imagery strategies. Long and Long, (1987) reported that good comprehenders in college are more mentally active while reading than are poor comprehenders. Good comprehenders engage in mental interactions with the text through visualizing, self-questioning, and inferring. Although poor comprehenders engage in some metacognitive activities, such as skimming, rereading and pointing to key words, they perform behaviors similar to those of good comprehenders, but without mentally activating operations needed for understanding.

Metacognitive reading skills include: skimming, activating relevant prior knowledge, constructing mental images, predicting, self-questioning, compre-

hension monitoring, summarizing and connecting new material with prior knowledge. Students cannot be expected to be competent with these skills because they are rarely taught and not everyone develops them independently. They need to be explicitly and continually addressed, practiced, polished and internalized. Improvements in these skills can lead to dramatic improvements in academic achievement. Students who are aware and in control of their metacognitive reading behaviors are at a distinct advantage because many of them involve monitoring one's comprehension, taking steps to clarify difficulties and restoring the comprehension process when it has broken down. Effective instruction in metacognitive reading skills requires that teachers explain the skills or strategies, model them for students, give examples, explain when, why, and how to use them, emphasize the value of flexibility in selecting specific skills to fit the particular context , provide guided practice on a range of texts, and give corrective feedback. Palincsar and Brown's (1984) reciprocal teaching procedure is specifically designed to develop four metacognitive reading skills: questioning, clarifying, summarizing and predicting. Through reciprocal teaching, eventually students are able to apply these metacognitive reading strategies on their own as self-regulating readers.

Research on college reading and study skills notes that there is a trend across studies showing that students' perception of their own control over learning has important implications for student performance in a wide range of areas (Maxwell, 1993). Students' perceptions of control tend to affect their time management, use of reading strategies, and test taking:. "...previous research on control theory suggests that unless students perceive that they have some control over and can influence their environment, their capacity to learn from instruction is limited" (110, p. 9).

In their critique of research on comprehension enhancing activities, Paris, Wixson and Palincsar (1986) note that not enough attention has been paid to students' self regulation of strategies they have been taught to use. They add that research has not told us much about what teachers need to do to ensure that students find these activities meaningful and internalize them, rather than following them blindly. They describe efforts to make readers more aware of the strategies they use and to foster more self-control in using them. A classic study in this genre (Brown, Campione and Day, 1983) compares three instructional conditions: 1. **blind** training, in which subjects are not told about why the activities they have been asked to perform are useful, 2. **informed** training, in which learners are induced to use a strategy and told why it is useful, and 3.**self -control** training, in which they are explicitly taught how to monitor and self-regulate their use of a reading strategy. Such research suggests that understanding the value of a strategy can give students a **personal rationale** for using it, which facilitates the continued use of the strategy (Paris, Wixson and Palincsar, 1986). This genre of research has demonstrated that

reading is enhanced and reading strategies tend to transfer when strategy training is accompanied by self-control training (Garner, 1987).

Garner's (1987) review of research on metacognitive strategy training in reading discussed efforts to improve comprehension through text reinspection. Garner identifies two main components of text reinspection: noting that one does not remember what one has read, and deliberately reprocessing segments of the text to provide the information. Garner and her associates found that to use this strategy successfully, readers need conditional metacognitive knowledge, i.e., knowing when and where to use text reinspection. Duffy, Book and Roehler(1983) found that explicit explanations created student awareness ,which in turn, stimulated student achievement. Garner argues that explanations about reading comprehension strategies should include: why the strategy should be learned; what the strategy is, how to use it, when and where to use the strategy and how to evaluate strategy use. Elementary school teachers do little direct instruction in how to comprehend text (Durkin, 1981). The tendency is for teachers to give students unguided practice. Finally, Garner reviewed the literature on text summarization, including the work of Brown and her associates on what students at different ages do and don't do: e.g. use of deletion rules, topic sentence invention rule, condensing, and revising. Garner (1987) found both high school and college students rarely integrate units of textual information, which would help produce succinct summaries.

Training studies have demonstrated that students can learn to use metacognitive strategies which can lead to better performance. Tobias (1987), using an aptitude-treatment-interaction (ATI) research paradigm focusing on mandatory text review, showed that unstrategic readers with low prior domain knowledge can be made to successfully review and refine their comprehension upon giving the wrong answers to adjunct questions. The results suggest that low-achieving students can be taught to use metacognitive strategies, such as text reprocessing, that may ultimately improve their reading comprehension. Knowledge about when to use strategies is an especially important form of metacognition (Pressley, 1984).

Research indicates that metacognitive knowledge about imagery is an important factor affecting its use. Images provide meaningful representations of material to be learned (Kulhavy & Swenson 1975; Paivio, 1971) . Such meaningfulness may facilitate both learning and retention. Kulhavy and Swenson (1975) investigated whether giving students instructions about images increased semantic recall of what they learned. The instructions they used told their subjects to form mental pictures of the events and activities in each paragraph before answering the question. Subjects in the image-instructed condition were told to use a specific strategy - mental pictures- and they were shown **when** to use the strategy. Embedded within the experimental booklets for these subjects, typed at the bottom of each page was, "Form a mental picture of these events before turning the page" (p. 49). Control

subjects were just told to read the material and answer each question correctly. The material was carefully constructed for this study. It consisted of 20 prose paragraphs on "The Island of Ako and Its People," and two questions on each paragraph. Essentially all of the nouns in the paragraphs and questions had concrete environmental referents. Image-instructed subjects performed better than controls on the first test, but the difference was not statistically significant. However, image-instructed participants performed significantly better than controls on the delayed test. The image instructions with strategic metacognitive knowledge about imagery increased the amount of text-content available over time.

In addition to this specific, conditional or contextual information about strategy use, individuals may need to know other information about using the strategies. What good is it to tell a subject when to form a mental image if the subject doesn't know exactly **what** is meant by a mental image?. The strategic knowledge base must include extensive declarative information, facts about the world in general and the particular domain, like the imagery strategy and its application to reading. For example, many students equate imagery with mental pictures and do not realize that mental images can be auditory, olfactory or from any of the senses - not just vision. Declarative knowledge interacts with strategy execution; it is often needed to implement the appropriately identified strategy. Knowing that images may be auditory can stimulate students to construct auditory images while reading. Finally, it may be important for a person being instructed to know step-by-step procedures for how to create one and regulate its use. Students can benefit from hearing an expert reader think aloud while constructing and using mental imagery in reading. Self-regulation includes the ability to monitor and evaluate strategy use. Readers may decide to supplement an auditory image with an olfactory image.

METACOGNITION IN TUTORING

Tutoring has a long history as an instructional method for developing students' knowledge and skills. Theoretical models of tutoring that include metacognitive factors affecting the tutoring process have been used to design tutoring programs and to plan tutor training that is designed to help students become self-directed learners (Hartman, 1990, 1993; Rings & Sheets, 1991; Condravy, 1995). In one tutoring model that emphasizes student development and metacognition, the student development component suggests that tutors should learn how to help students monitor their progress. It also suggests that tutors should confront students who fail to take responsibility for their own learning, and should help students develop effective communication skills and learn about instructional support and other campus resources. The metacognitive component suggests that tutors should teach students a problem solving model with four components: *individual learner characteristics* of motivation, learning styles and culture; *task*, or specific learning

goals; *strategies*, including predicting test questions, categorizing information, and managing time; and *materials*, including use of print and media. Tutors should help students become aware of the components of the model and help them implement specific strategies designed to meet their individual learning goals (Rings & Sheets, 1991).

Another tutoring model describes good teaching as helping students "discover what the learning process is about so that they can become lifelong learners" in addition to helping them master content (Gourgey 1992, p. 67). Her tutoring model is intended as a guide for the tutoring process and as a blueprint for tutor training. Its components are dialogue, developing metacognitive skills, response to affective (emotional) needs and reeducation about the learning process. Gourgey notes that often students need reeducation about the learning process because they have unrealistic expectations and do not "appreciate the importance of intellectual struggle, incubation, and understanding ideas rather than just following procedures" (p. 67).

When Condravy (1995) asked tutors to identify methods that were most effective for promoting learning, tutors' responses showed the need to address emotional, cognitive and metacognitive aspects of learning. After completing a nine-hour training program, Condravy's tutors reported spending most of their teaching efforts on students' metacognitive needs, followed by emotional needs, especially motivation, and, finally, students' cognitive needs.

Research by Hostetter (1994) focused on teaching metacognitive strategies to international students who were repeating a developmental reading course. Tutors were trained to tutor metacognitively, to plan, monitor and evaluate their tutoring sessions and to teach students metacognitive reading strategies, such as comprehension monitoring and identifying error patterns so they could change them. The tutorials followed a structured format consisting of: warm-up, mental preparation for testing, testing, discussing passages, and discussing questions and answers. The results suggest that students who received metacognitive tutoring improved in reading comprehension and did better than students who did not receive metacognitive tutoring.

Many students experience academic difficulty because they constantly focus on retaining subject matter content without first learning the intellectual skills needed to support that effort. In order for the students to function intelligently, teachers (including tutors) need to develop both cognitive and metacognitive skills as well as positive affect of emotions, attitudes and motivation.

THE BIG PICTURE: THE BACEIS MODEL OF IMPROVING THINKING

The B A C E I S model of improving thinking (Hartman & Sternberg, 1993), described in the Preface, underlies the organization of this book as well as my teaching and research. The BACEIS model is a comprehensive framework of factors internal and external to the student which affect a student's academic performance. Factors internal to the student are cognition and affect; factors external to the student are academic and nonacademic environments. The BACEIS acronym stands for the following: **B**=behavior, **A**=affect, **C**=cognition, **E**=environment, **I**=interacting, **S**=systems (Figures 1 & 2). The model suggests that internal factors of cognition and affect are related to each other and are also related to interacting external factors from academic and nonacademic environments. The combination of these factors and their reciprocal influences has implications for successful performance of academic work. Such information may be useful for understanding students' academic performance and for designing instruction which improves it. To promote intellectual development, a teacher (or tutor) may intervene at any point in this complex array.. The cognitive part of the internal supersystem is made up of two parts: cognitive and metacognitive. The cognitive component has three major applications: critical thinking, creative thinking and learning strategies. The affective part of the internal supersystem consists of motivation, affective self-regulation and attitudes. The external supersystem consists of the academic environment (teacher characteristics, content, class environment & instructional techniques) and nonacademic environment (socio-economic status, family background and cultural forces). These environmental factors interact with each other and with the rest of the BACEIS system components. The combination of these interacting variables leads to behavioral consequences regarding intellectual performance.

DEVELOPMENT OF METACOGNITIVE STRATEGIES

This section describes some of the techniques I have used to develop metacognition in tutors and tutees in the tutoring and cooperative learning program I directed and in my undergraduate educational psychology students who are preparing to become teachers. Consequently, what these students learn is intended to have two functions: to develop their own ability to learn metacognitively, and to learn strategies for developing metacognition in their current (from their fieldwork experience) and future students.

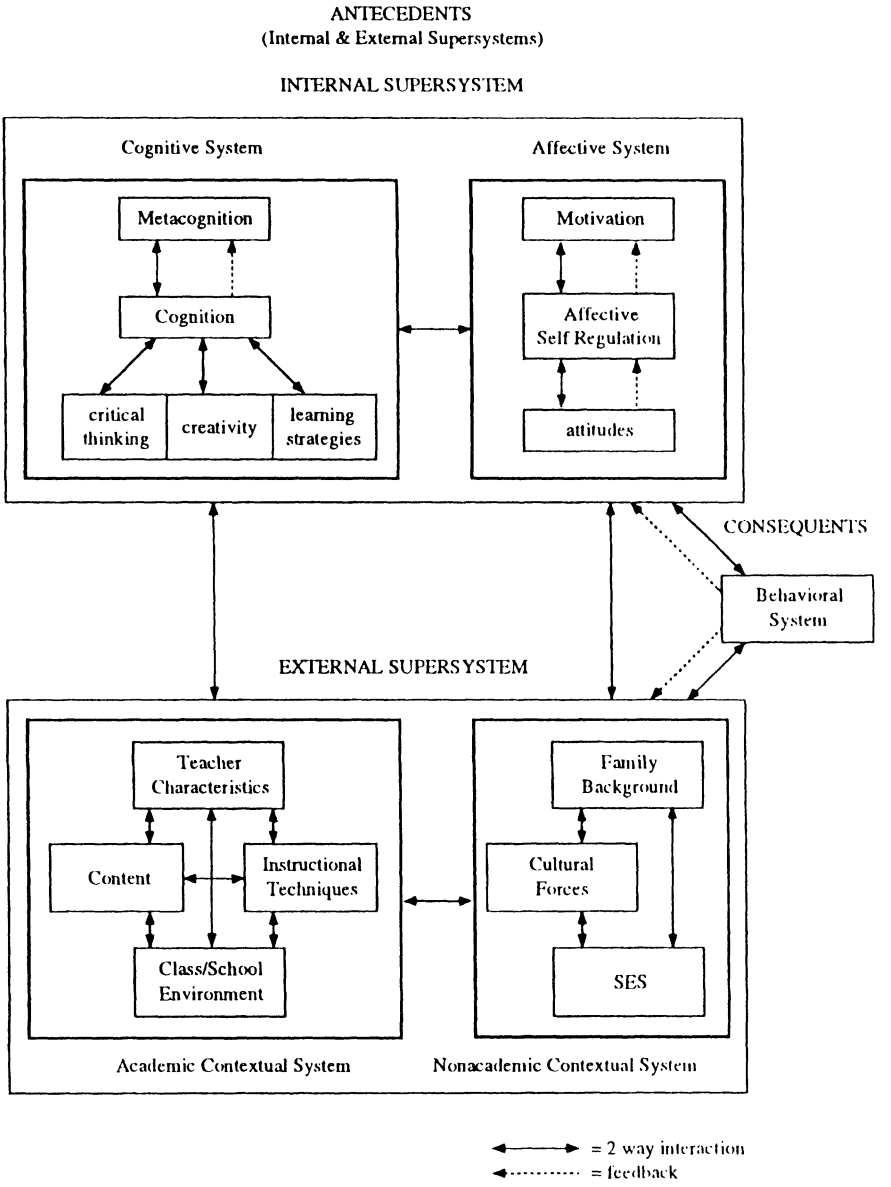

Figure 1. BACEIS model components

(*Hartman & Sternberg,* 1993)

ANTECEDENTS - INTERNAL SUPERSYSTEM

Keisha's Cognitive System

Metacognition
- skim, image
- monitor comprehension
- self question, look back

Cognition
- encode information
- clarify
- infer

Critical Thinking	*Creativity*	*Learning Strategies*
-evaluates alternative energy sources	-designs new way to purify gasoline	-selective attention

Keisha's Affective System

Motivation
- interested in content and wants to answer questions correctly
- wants to please parents and teachers

Affective Self Regulation
- expects to be good reader
- values reading

Attitudes
- good reading self concept
-curious about content due to father's occupation
- persists when reading difficult material

EXTERNAL SUPERSYSTEM

Keisha's Academic Contextual System

Teacher characteristics
-reading specialist
-extensive teaching experience
-positive towards students
-diverse teaching repertoire

Content (text)
-gasoline emissions
-ozone in atmosphere
-cars v. mass transit
-alternative energy sources

Class Environment
-students challenge authority
-resources accessible
-content at appropriate level

Instructional Techniques
-reciprocal teaching
-imagery formation

Keisha's Non-academic Contextual System

Family Background
-native speakers of English
-family reads and discusses books at dinner
-brothers/sisters good readers
-father owns gas station

Cultural forces
-need reading as survival skill in society (signs, labels, job applications)
-television inhibits reading

Socio-economic Status
- money for books, newspapers
-leisure time for readings
-father's income crucial to support family

BEHAVIORAL CONSEQUENTS

Keisha correctly answers comprehension questions, paraphrases text, self regulates reading; writes essay, rejects author's conclusion, proposes new technology

Figure 2. Application of BACEIS model to reading. (*Hartman & Sternberg,* 1993)

Reading Metacognition

There are many techniques I have used to help students develop their metacognitive reading skills. Some of these techniques are identified in Figure 2, which applies the BACEIS Model to the improvement of Keisha's reading comprehension in a classroom lesson about energy, fuel and the environment. One of the first homework assignments in my undergraduate educational psychology class requires students to define ten strategies and reflect on their use of these strategies in reading Chapter 2 of our educational psychology text and in general (Table 1).

Table 1 Reading Metacognition Homework

Define each term, then look back at what you have read so far in this chapter and analyze your use of metacognitive reading strategies. Indicate (Yes/No) which of the strategies below you used when reading this material and indicate your general use of each of them when reading.

Metacognitive Reading Strategies

Strategy	Definition	Used Here	Generally Use
1. skim		yes no	yes no sometimes
2. Predict		yes no	yes no sometimes
3. Image		yes no	yes no sometimes
4. check comprehension		yes no	yes no sometimes
5. clarify		yes no	yes no sometimes
6. self test on content		yes no	yes no sometimes
7. review		yes no	yes no sometimes
8. summarize		yes no	yes no sometimes
9. activate prior knowledge		yes no	yes no sometimes
10. connect prior knowledge to new information		yes no	yes no sometimes

Then there is an in-class cooperative learning activity in which groups of students compare their definitions of the metacognitive reading strategies, tally the results of their use of these strategies, compile the results across groups to develop a class-wide profile and discuss the implications on two levels: the reading strategies that they use, from their perspectives as learners, and the class's reading strategies, from their perspectives as teachers.

Another technique is to teach students the difference between reader and writer-based summaries (Anderson & Hidi, 1988/1989) and give them extensive practice and feedback preparing reader-based summaries. These are emphasized because my students often have difficulty differentiating the author's main ideas from their own, and they tend summarize from a writer-based perspective, often missing important ideas on the topic due the students' subjectivity.

A third technique is Reciprocal Teaching. Reciprocal Teaching is a cooperative learning method of improving reading comprehension that can also be used in individual tutoring/teaching. In reciprocal teaching a teacher/tutor and a group of students take turns leading discussions about specific segments of text using reading strategies of questioning, clarifying, summarizing and predicting (Palincsar & Brown, 1984). Instructional techniques involved are: demonstrate, or model and explain; practice with feedback; dialogue, or "simple conversation with a purpose" (Palincsar, Ransom & Derber, 1988/89, p. 37); scaffold, or provide students with temporary support; and take turns leading text dialogues. The combination of these techniques leads to student self- regulation or self-management of reading comprehension. A review of research on reciprocal teaching (Rosenshine & Meister, 1994) shows two different forms of the method used in studies by the developers and their associates; one involves explicit instruction in the reading strategies *before* the dialogues begin. Consistent with this method is a five-stage sequence of reciprocal teaching instruction: (1) teacher demonstration; (2) student learning and guided practice in using the four comprehension strategies; (3) coordinated practice using the strategies with segments of text in small groups led by the teacher, where students alternate with the teacher leading text dialogues based on the four reading strategies; (4). practice using the strategies in small groups of students with the teacher only observing and guiding as needed; and (5). student competence and self-regulation. These are described in more detail in Hartman (1994). Students learn to use Reciprocal Teaching to improve their own reading comprehension and to improve that of their current and/or prospective students.

A fourth technique I use to improve students' reading metacognition is teaching them to create graphic organizers (external, visual representations) summarizing the main points from our textbook. One procedure for teaching students to create graphic organizers is discussed in the next section.

After teaching students these various metacognitive reading strategies, I encourage them to experiment with them in all of their classes to determine which work most effectively for them in different subjects and situations.

Graphic Organizers

Graphic representations can be used to understand text and solve a variety of problems. Graphic organizer techniques can help students analyze text and see how it is structured. Networks of related ideas (schemata) that the reader brings to the text set up expectations that influence understanding and interpretations of what is read. (See Chapter 9 for an example of a concept map). If there is a mismatch between the reader's and writer's ideas, comprehension can break down. Learning to understand the structure of ideas in a text can improve comprehension (Mulcahy, 1987). For example, teaching students *story grammars*, e.g., a novel usually has a protagonist, antagonist, climax, and denouement helps the reader set up appropriate expectations that make the text easier to understand. Several of these organizer techniques have been found to be especially useful for reading text. Some graphic organizers that can be used to understand text are flow charts, concept maps, Venn diagrams and tree diagrams. Jones et. al. (1988/89) identified other graphic organizers found to be useful for reading text: network trees, fishbone maps, cycles, spider webs, continua/scales, series of events chains, compare/contrast matrices and a problem/solution outlines (Jones et. al., 1988/89). "A good graphic representation can show at a glance the key parts of a whole and their relations, thereby allowing a holistic understanding that words alone cannot convey "(Jones, Pierce and Hunter, 1988/1989, p. 21).

Creating Graphic Organizers through Scaffolding

After years of simply modeling for students how they can create graphic organizers as learning strategies with only moderate success, I changed to a scaffolding approach, which has been much more effective for developing this metacognitive strategy. Scaffolding means providing support (models, cues, prompts, hints, partial solutions) to students to bridge the gap between what students can do on their own and what students can do with guidance from others. The goal of scaffolding is for students to become independent, self-regulating thinkers who are more self-sufficient and less teacher-dependent. Scaffolding is an especially effective teaching approach for developing higher level cognitive strategies (Rosenshine & Meister, 1994) and is discussed in greater detail in Chapter 8, "Teaching Metacognitively". I use the following steps in my scaffolding plan for teaching students to create effective graphic organizers:

1. I show and explain a variety of traditional examples of graphic organizers, such as those identified above, and more innovative, untraditional types, such as ocean scenes, ladders, and our galaxy. Students learn about three uses of graphic organizers: for teaching, learning, and assessment. For half of our midterm and final exam questions students have to create graphic organizers of their answers. I ask students about their past experience with graphic organizers, and usually find out that few students have had experience creating their own graphic organizers, but most students recognize them as something they have seen.

2. Students read about what graphic organizers are, when, why and how to use various types of them. One source (Jones, et. al. 1988/89) provides information on why and how to create graphic organizers to comprehend text and it provides illustrations of a spider map, continuum/scale, series of events chain, compare/contrast matrix, problem/solution outline, network tree, fishbone map, human interaction outline and cycle. Another source focuses on concept maps and Vee diagrams (Novak, 1998).

3. As a homework assignment students are given a partially completed matrix to finish (Table 2). Students are expected to use the information provided as a model for their completions. Many students need explicit instructions to write their own "How" in the second row and their own "What, Why and How" in the third row. I give students feedback on what they write and where they write it. For example, it's not uncommon for students to put information on "why" an idea is important in the section on "how" they might use it, and vice versa.

4. The next homework assignment requires students to complete an empty matrix entirely on their own. Students get feedback, as before.

5. For the next homework assignment students create their own graphic organizers, but it can't be a matrix . Then I give students additional examples of standard and innovative models and specific criteria for constructing and evaluating graphic organizers. Students evaluate their own homework graphic organizers using these criteria. These criteria are:
   a. neat and easy to read
   b. ideas are expressed clearly
   c. ideas are expressed completely
   d. content is organized clearly and logically
   e. labels/other strategies (colors, lines) to guide reader's comprehension
   f. main ideas, not minor details, are emphasized
   g. it is visually appealing
   h. the reader doesn't have to turn the page to read the words

6. Have students develop a graphic organizer in a cooperative learning group, but they can't use a matrix. Metacognitive processing tends to spontaneously occur during cooperative learning (Artzt & Armour-Thomas, 1992). Students discuss the advantages and disadvantages of different structures, they discuss what concepts to include and exclude, and they self-regulate their attempts to meet the criteria identified above. Once their graphic organizers are completed, the groups show their graphic organizers to the other groups which give them feedback based on the criteria identified above. I supplement the groups' feedback with my own comments, as needed.

7. For homework, students develop graphic organizers completely on their own, but not using the matrix format. Group members give each other feedback on the extent to which they have met the established criteria.

8. Finally students are expected to be able to create and critique their own graphic organizers. Because half of the midterm and half of the final exam in our course require students to put their answers in the form of graphic organizers, students know they are accountable for their mastery and the ability to self-regulate their development.

Modeling Metacognition

An important strategy for developing metacognitive knowledge and skills is for teachers to provide models of metacognition in everyday-life and/or school. Modeling is based on Bandura and Walters's (1963) theory which highlights the importance of observation, identification, imitation and motivation in learning. The previous section on scaffolding the creation of graphic organizers involves repeated and varied modeling. Teachers can think out loud to externalize their thought processes, serving as an "expert model," so students can hear effective ways of using metacognitive knowledge and skills. Modeling is often a component of scaffolding, as can be seen by reviewing the first steps of both Reciprocal Teaching and Cognitive Behavior Modification. Many students appreciate seeing models of higher-level metacognitive strategies, especially those involving everyday life experience. Table 3 shows one way I have modeled executive management metacognition in everyday life. Table 4 shows one way I have modeled strategic metacognitive knowledge for reading and writing strategies.

Table 2

Partially Completed Graphic Organizer

Complete the graphic organizer below using ideas from this chapter of our text. Tell *what* the ideas are, *why* they're useful and *how* you might use them. Part is filled out for you as a model; please complete the rest of it based on information from Chapter 2 of our text. Add your own "*how*" to the second row and your own "*what, why* and *how*" in the third row.

WHAT is the idea?	**WHY is it useful?**	**HOW might I use it?**
Reader-based summary	To make sure I have identified, understand and can remember the author's main ideas.	After reading a chapter of a textbook, I'll look for the author's signals about the main ideas, identify the most important ones, check my understanding by briefly writing them in my own words. I'll be objective and selective.
Writer-based summary	To remember the ideas I'm personally most interested in.	

Table 3
Model: Executive Management Metacognition in Everyday Life

Planning: Decision Making
Identify and define the problem or task.
Get Michael an excellent doctor who knows about his disease and can follow up on the specialist's recommendations; Michael's doctor of 20 years didn't.
Diagram or represent the problem or task internally and/or externally.
Create visual image of the x-ray of Michael's liver that the specialist showed me as he said Michael should get on a transplant list and start taking Actigall.
Create along with that a visual image of his doctor of 20 years
Select processes needed to perform the task.
Identify potential sources of the information.
Contact those sources to see who they recommend in our area.
Choose a doctor and make an appointment.
Explore alternative approaches and select the best.
Make sure we look at more than one type of source.
Don't just rely on people we know, use the Internet to identify top people in the New York area.
Sequence the processes and approaches into an effective order.
First make phone calls to 3 people we know because we can do that right away
Schedule time to search the Internet.
Search the Internet.
Budget time and resources for performing the task.
Spend minimal time on each of the 3 phone calls, 5 to 10 minutes each.
Plan to spend at least two hours searching the web.
Anticipate potential difficulties and how to overcome them.
If our sources don't pan out, see if they can give us leads.
Identify other possible doctors in case the first one doesn't work out.

Monitoring: Checking Implementation in Progress
Comprehension
Do I really understand what kind of doctor Michael needs?
How well do I understand the timing of his need for a new doctor?
Approach
Are we going about this doctor search in the right way?
Are there other ways we could be looking for a doctor?
Memory
What other people, organizations or institutions do I know of that might help us find a liver specialist familiar with PSC?

(Table 3 continued)

Evaluating: Assessing Implementation

Use internal and external feedback to judge your own performance.

The doctor from the first hospital was good because he got Michael on Actigall right away.

The doctor from first hospital was disappointing because he had no interest in putting Michael on the transplant list and I didn't like his "bedside manner".

Use judgements from internal and external sources to plan future performance.

If it were me, I'd get a new doctor. How does Michael feel? I'll ask him. Michael feels the exact same way. New doctor it is!

Develop and implement specific action plans to improve your performance.

We'll contact the doctor from the second hospital who published an article on Michael's disease and who spoke recently at a local conference on liver diseases. After we see him, we'll evaluate him to see if we want to stay at the second hospital or try a third.

Table 4

Models of Strategic Metacognitive Knowledge

WHAT (FACTS)	WHEN & WHY (CONTEXT)	HOW (PROCEDURES)
Clarify is to fix up understanding or to make clear.	When something is confusing/ unclear, vague, ambiguous; to attain comprehension.	Use context clues in the text. Look back. Look ahead. Ask questions.
Revise is to change or modify.	After writing a draft. To improve a paper.	Get feedback on a draft. Internal (self) External (others) Use feedback to correct, refine, elaborate, delete.

When providing models such as those in Tables 3 and 4, I generally explain each component and ask questions to monitor and evaluate students' understanding of the concepts. Then I try to elicit students' own examples of each component of the model and have students work in groups, giving each other feedback on the quality of the examples as I circulate among the groups providing individualized feedback.

Teachers can use the think-aloud method (discussed later in this chapter) to serve as expert models showing students how to use metacognitive knowledge and strategies when working on a variety of tasks; for example, to let students see and hear how they plan, monitor, and evaluate their work and how they would approach tasks like their students'. When the thinker-talker is the subject-matter expert, the process allows the expert to model their own thinking for students. This modeling shows how to think about the material (knowledge, skills, procedures etc.). It lets students hear what goes on in an expert's head when a text is read, a homework assignment is attacked, study for a test is planned, an essay is written, an error is found, or a problem is solved. It also should include statements from the expert that externalize her/his feelings so that students can learn how to self-regulate their own emotions. When modeling academic performance, it's a good idea to intentionally make occasional mistakes, so that students can observed becoming aware of them and strategies for recovering from them and self-correcting. Meichenbaum and Biemiller (1998) state that think-aloud modeling may be in the form of self-questions (e.g., Did I carefully check my work?) or self-instructional directive statements (e.g., That's not what I expected. I'll have to retrace my path). They recommend that teacher use think-aloud modeling for showing students how to: summarize, access prior knowledge, self-monitor, obtain help, and self-reinforce. This modeling should involve communicating with students so that the lesson is an interactive dialogue instead of a monologue, and modeling should be gradually phased out as student competence and responsibility increase.

Self-questioning

Questioning and self-questioning strategies are effective ways of promoting self-directed learners. Self-questioning can guide the learner's performance before, during, and after task performance; it can improve self-awareness and control over thinking and thereby improve performance; self-questioning can .improve long-term retention of knowledge and skills; it can improve the ability to apply and transfer knowledge and skills students learn; and finally, it can improve attitudes and motivation as a result of improved performance. Research on self-questioning shows that questions created by the student are much more effective than questions given to the student by someone else Model self questioning, and discuss and illustrate how it is used in school and everyday life situations. Self-questions such

as " Have I left out anything important?" can help a student self-direct in identifying the omission of important points or examples. Ask students questions such as "How do you prepare for a test? How would you plan, monitor, and evaluate a surprise party?"and have students generate and use their own self- questions. The more students practice generating and using self-questions in diverse situations the more likely they are to develop the habit of self- questioning so it becomes a skill, which is used automatically and unconsciously as the situation requires. The I DREAM of A approach to writing (Hartman, 1993) and to solving math/science problems (Hartman, 1996; see Chapter 9) is designed to help learners become more self-directed. If students can't do this individually, try doing it in pairs or small groups. Teachers (or tutors) can listen to students executing tasks while using their self-questions and give them feedback on their questions and answers. They can encourage students to keep a readily accessible prompt sheet for their own self-questions to stimulate their thinking of the kinds of questions to ask in a particular situation. It is important to regularly have students adapt their self-questions to the needs of the specific subject and task and not impose preformulated questions on them.

Teachers should not be satisfied with putting students in situations which require them to use self-questioning (or any strategy they want students to use). **Practice isn't enough.** It is also important to provide **explicit instruction** in when, why and how to use self-questioning; students need to understand the rationale and effective procedures for self-questioning so that they can recognize appropriate contexts for its use, so that they have criteria for evaluating their self-questioning, and so they can self-regulate its use.

Table 5 shows some of the types of self-questions students can ask to plan, monitor and evaluate their thinking in a range of academic domains. By focusing on a range of subjects students can see some of the similarities and differences in metacognition across subjects. Perceiving the similarities may promote positive transfer and perceiving differences may inhibit negative transfer of metacognitive strategies. Teachers should give students examples of questions like these to stimulate students' thinking about the kinds of questions they may use in different subjects, but teachers should emphasize that students need to create their own questions that are situation- and task-specific. Teachers and tutors should be sure to emphasize the value of student-generated, task-specific questions rather than pre-formulated questions.

Assessment and Error Analysis

Students often joke about their graded papers being put in the "circular file". Many students waste a valuable resource their teachers give them that could help them to improve their future performance - feedback - both oral and written. In

most classes there are several opportunities for students to obtain information from the teacher on their mastery of course concepts and skills. Yet frequently written feedback ends up ignored and only the grade is noted. Students should be encouraged to reflect on what feedback they've received, how that feedback is best interpreted and how it can be used to improve their future performance.

However, assessment is most effective when it also includes students' self-monitoring and self -evaluating so that they can manage their own learning. One method I use to promote student self-monitoring and self-evaluating is error analysis. Metacognitive knowledge about error analysis includes:

1) Declarative knowledge: Error analysis is a systematic approach for using feedback metacognitively to improve one's future performance. It involves obtaining strategic metacognitive knowledge about one's mistakes and recycling that knowledge for self-improvement.

2) Conditional/Contextual Knowledge: Error analysis has several potential benefits. First, it gives students a second opportunity to master important material. Second, it develops students' metacognition, both strategic knowledge and executive management, as students evaluate their test performance, identify errors and possible errors patterns, and plan for the future For example, it can help students anticipate their specific likely errors and self-correct them before turning in a test. Third, it helps internalize students' attributions so that they recognize that their educational outcomes (grades) are a result of their own efforts, actions and strategies - factors within their control- rather than attributing their performance to external factors outside their control, like the professor or bad luck. This could improve students' feelings of self-efficacy, their academic self-concept in the specific subject area, and perhaps transfer to their general academic self- concept.

3) Procedural knowledge: Error analysis requires identifying what the correct information/answer/approach is, and identifying what errors, omissions, etc., were made, determining why they occurred, and planning how to prevent them in the future. When doing error analyses my students are required to: 1. Identify what their wrong answer was and what is the correct answer (declarative knowledge). 2. Determine specifically why they got the answer wrong (contextual knowledge) and 3. Formulate an action plan on how they have now learned and understood the material and how they will remember this information (procedural knowledge).

Table 5

Sample Student Self-Questions for Managing School Subjects

Thinking Objective	PLANNING	MONITORING	EVALUATING
Reading	What do I already know about this topic? What am I expected to learn from this reading? How much time should it take for me to read this?	Is there anything I don't understand? Can I figure it out on my own? Which ideas are most important? How can I remember what I've read so far?	Did I understand and remember everything? Which reading strategies worked best this time? How can I read with better understanding next time?
Writing	What is the purpose of this essay? What should be in the introductory paragraph? How should I put these ideas in the best order?	Am I elaborating on all of my main points? How clearly am I expressing my ideas? Am I making any spelling or grammar mistakes?	What was best about my paper? Why did I make those spelling and grammar errors? How can I best prevent those mistakes next time?
Mathematics	What do I have to find? Have I ever solved a problem like this before? What formula should I use?	Is my diagram of the problem right? Am I using the right formula? Am I making any careless mistakes?	Does my answer make sense? Is the right answer? Did I use an appropriate method to solve this problem?
Social Studies	What causes of World War 11 am I supposed to remember? Which are the key events I need to understand? How can I make sure I will remember them for the essay exam?	Am I confusing the political causes with the social causes ? What do they mean by the law of supply and demand? Am I giving up-to-date answers to the questions on current events?	Did I correctly identify all the important causes of World War 11? What else should I have included in my discussion of the critical events? What did I learn from this history lesson that applies to the world today?
Science	How can I design research to test this hypothesis? What are all of the critical variables that need to be considered? Which variables need to be controlled?	Does the research design validly test this hypothesis? Should I try a different approach? Am I recording all the observations accurately?	How effective was my experimental design? Were my conclusions justified by the results? How could I be a more accurate observer and recorder next time?

Preliminary analysis of the quality of students' error analyses suggests declarative information is relatively easy for students to produce, contextual knowledge is moderately difficult, and procedural knowledge is the most difficult for students to generate. Sample error analyses (additional procedural knowledge) are in the Appendix.

Error Analysis Model

1. **What answer I had AND what the answer really was. OR WHAT I did wrong AND what I should have done.**
2. **WHY did I choose the wrong answer? OR Why did I do it wrong?**
3. **HOW will I remember what I now know is the correct answer? OR How will I make sure I don't make the same mistake again?**

In all three steps the student must focus on the specific content involved in the errors rather than focus on general causes of errors, such as not studying enough.

After taking exams, I teach students error analysis procedures and require them to perform error analyses as homework assignments. Occasionally, for each written error analysis a student performs correctly, the student may recapture half of the points that were lost for each test item, if it appears that the student has now mastered the material and understands his or her mistakes.

When reviewing this chapter for the book, Gourgey introduced me to a more comprehensive method used in medical education for test error metacognition that emphasizes students' mastery of the topic. Pelley & Dalley's (1997) "question analysis" is intended to help students make a broader analysis of test questions than just a literal interpretation because a narrower, more literal interpretation can constrain their studying and limit learning. Their procedure has four steps: identifying topics, understanding the correct answer, understanding wrong answers, and rephrasing the question. Pelley and Dalley encourage students to ask questions such as, "How would I have had to study to know that the correct answer was right?" "How would I have had to study to know that each wrong answer was wrong?" Focusing on the topic rather than the question helps students understand material more deeply, so they understand how ideas are interrelated, and therefore students are able to correctly answer more and different questions.

Thinking Aloud

As mentioned in the section on modeling, thinking aloud is an excellent technique for developing metacognitive knowledge and strategies. It is a

fundamental component of Cognitive Behavior Modification (Meichenbaum, 1977), Pair-Problem Solving (Whimbey and Lochhead, 1981) and the I DREAM of A approaches to writing (Hartman, 1993) and problem solving (Hartman, 1996).

When teaching my students to think aloud, I provide them with strategic metacognitive knowledge about this technique so that they can use it in appropriate situations and with proper procedures. The section below provides a detailed example of strategic metacognitive knowledge I give to students to maximize the effectiveness of their use of thinking aloud.

WHAT is Think Aloud?

It is a technique of externalizing one's thought processes as one is engaged in a task that requires thinking. The thinker says out loud all of the thoughts and feelings that occur when performing a task (e.g. solving a problem, answering a question, conducting an experiment, reading through lecture/textbook notes etc.) . It is a method that can be used by a teacher or tutor, two students working together, or a student working alone. Using the think-aloud process with two students - where one serves as the THINKER while the other serves as the analytical LISTENER - is known as "pair-problem solving" (Whimbey & Lochhead, 1982). The thinker verbalizes out loud ALL the thoughts that arise in the process of completing an academic task. The listener actively attends to what the thinker says, examines the accuracy, points out errors, and keeps the thinker talking aloud.

WHEN should the Think Aloud process be applied?

- When the teacher wants to demonstrate to the student what and how to think about academic content and strategies.
- When the teacher wants to help guide the student in learning what and how to think about academic material and tasks.
- When the teacher wants to diagnose or assess what and how the student thinks and knows.
- When there is a desire to become more thorough, precise and systematic when performing tasks that require thinking.
- When the teacher wants the student to become more aware of and more in control of his or her own knowledge, skills and attitudes.

WHY should Think Aloud be used?

- It helps prevent passivity and rote learning.
- It helps students communicate to the teacher what they know and how they approach academic tasks. This helps the teacher identify and diagnose misunderstood or misused concepts, rules, facts, important omissions and inadequate or incomplete knowledge, approaches, or skills.
- It helps students think more precisely, carefully, and systematically.
- It helps students examine their own knowledge, skills and attitudes.
- By hearing themselves think, they become more aware of their strengths and weaknesses.
- Through combining this self-awareness with feedback from the listener, students can check their own performance and make appropriate changes as needed.
- It increases students' control over themselves as learners and can improve their academic (and nonacademic) performance.
- Students working together can discover errors, misconceptions, disorganizations, and other impediments to intellectual performance.

HOW to do the Think-Aloud process

How to Think Aloud: Problem Solver's Task

1.Translate your thoughts (ideas, images etc.) into words and recite them aloud.

2. Verbalize aloud all the steps you go through when solving problems. Don't censor. No thought or step is too small, easy, obvious or unimportant to verbalize.

3. Verbalize all the thinking you do before you start to solve the problem (e.g. what you are going to do, when, why, and how). Even second-guessing yourself is important to verbalize aloud, e.g., "What's the best way to solve this problem? I think I should use that long, complicated formula we were using a couple weeks ago. What was it called, the quadratic equation?. No, maybe not. Maybe I'm supposed to use the formula we did in class yesterday".

4. Verbalize all thoughts as you proceed, e.g., "OK, I'm almost through with this division problem. Now that I have my answer, all I have to do is multiply to check and see if my answer is right." Verbalize ALL the thinking done before, during, and after work. The verbalization must include plans of what to do, when certain steps are taken, why steps are used (not used), and how to proceed with each thought. For example, I think I should use that long, complicated formula we were talking about a couple of weeks ago. No, maybe not. Maybe I'm supposed to use that new one we covered in class today."

How to Listen Analytically: Listener's Task

The following guidelines for listening while engaged in pair-problem solving are adaptations of Whimbey & Lochhead (1982).

1. Think along with the problem solver. Follow every step and make sure you understand every step. If not, ask a question. Have the problem solver identify and define important terms, variables, rules, procedures etc. Make sure the problem solver vocalizes all the steps and does all the work. If the problem solver skips over a step without thinking aloud, ask her or him to explain the missing thought.

2. Do NOT work on the problem independently. Listen to and work along with the problem solver.

3. Never let the problem solver get ahead of you. Whenever necessary, ask the problem solver to wait so you can check a procedure or computation etc. and catch up. If the problem solver is working too fast, slow her or him down so you can follow carefully, analytically, and accurately.

4. Check the problem solver at every step. Don't wait for his or her ultimate solution or answer. Check everything - each computation, diagram, procedure, etc. In the back of your mind, constantly ask yourself, "Is that right? Did I check that?" To promote precise thinking, have the thinker carefully define important terms and variables.

5. If you find an error, avoid correcting it. Point it out and try to get the problem solver to self-correct. If he or she gets stuck, ask questions to guide thinking in the right direction. If necessary, give suggestions, hints or partial answers; only give the answer as a last resort. Let the problem solver know that you are not trying to be difficult, you are trying to help him or her become an independent problem solver. If no amount of suggestion helps the thinker and you must give information or demonstrate a procedure, assign a similar task as follow up and require the thinker to do it aloud. Let students know that by doing these things, you're not being picky or critical, you're helping them to become more self-directed learners and to develop important academic knowledge, skills and attitudes.

The teacher observes each pair, monitors progress, and provides feedback on the process. To make sure listeners really do their job, periodically teachers should ask listeners to summarize the steps the problem solvers used. The following

activities were suggested by Larcombe to help student pairs in elementary grades or remedial high school students learn to externalize their mathematical thought processes: 1) Students take turns describing the rules they use. 2) Students describe to each other how the parts fit together when doing a construction task. 3) Working with concrete objects at first, students can describe operations used when calculating, and 4) One student must guess an object, a mathematical representation or a graphic based on another student's description.

There are several limitations of the Think Aloud method. Knowing how to use Think Aloud effectively includes the thinker's awareness of the types of difficulties that might be encountered (awareness) so that they can be prevented or at least overcome. The following factors may cause some student difficulties: belief that rote learning (memorization without understanding) is acceptable; lack of familiarity with the academic content, inadequate skills for executing the academic task; inadequate knowledge and skills of either or both the thinker and listener; the need for more practice in using the technique; the cultural background of the student, leading some students to be reluctant to reveal private thoughts; and that thinking and listening are faster than speaking.

Having this strategic metacognitive knowledge about the Think-Aloud technique makes students are more likely to use it because understanding the conditions and context of its use, i.e., why it's a useful strategy, makes it more meaningful, and because by having procedural knowledge, they know what methods to use when applying it in various situations.

SUMMARY AND CONCLUSION

Metacognition is an essential ingredient of self-directed and self-regulated learning. There are numerous forms of metacognition that can be used in academic learning and everyday life. With extensive and varied use, metacognitive strategies and knowledge can be refined and used automatically as needed in skilled performance. However, because not all students develop and use metacognition spontaneously, teachers need to provide students with explicit instruction in both metacognitive knowledge and metacognitive strategies. The most important point is that through practice of self-regulation, students can develop voluntary control over their own learning. Teachers can enhance students' awareness and control over learning by teaching them to reflect on how they think, learn, remember and perform academic tasks at all stages before, during and after task execution. Finally, and most importantly, teachers should repeatedly emphasize, and demonstrate through actions, that students are responsible for and can control their own outcomes in their education and their everyday lives.

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APPENDIX

Sample Error Analyses

Reading Comprehension

Test Item:
The content in paragraph 3 indicates that the writer's belief was:
a). The first stage of the civil rights movement was a failure.
b) Supreme Court decisions do not have as much influence on society as actions by the Congress.
c). Social movements are able to influence the political process.
d). The costs of civil disobedience sometimes outweigh the benefits.

Error Analysis of Item
1. What I got wrong and what the right answer is.
I thought the answer was "a ", but now I know the answer is "c".

2. Why I got it wrong.
I confused my beliefs with what was actually in the text. I though of what the author called "the first stage" as a failure, but the author didn't say or imply that. The author was really trying to make a different point.

3. How I will remember this and prevent future similar mistakes.
My teacher taught me to ask myself questions about what I read. So I'll ask myself a question like, "Is this what I think or is this what the author is really saying?"

Math problem
Subtract

$$\begin{array}{r} 2668 \\ -1629 \\ \hline 1049 \end{array}$$

1. What I got wrong and what the right answer is.
The answer 1049 is wrong. The correct answer is 1039.

2. Why I got it wrong.
I forgot to change the "6" in the tens column to a "5" after borrowing to subtract 9 from 18 in the ones column.

3. How I will prevent mistakes like this in the future.
From now on, instead of trying to remember I borrowed in my head, I will cross out the number I borrowed from, and write the new number above it.

For example,

```
    5
  2668
- 1629
  1039
```

Essay

1. What I got wrong and what I should have done.
There were two major things wrong with my paper. First, I didn't elaborate on my ideas enough. I should have developed the ideas in my topic sentences more and given more examples to support my points.
The paper was not as well organized as it should have been. In some paragraphs the ideas I started off with were not related to later ideas in the paragraph. Then in the next paragraph I would pick up on ideas I started in the previous one. I should have followed through with related ideas in the same paragraph instead of jumping around.

2. Why I did this wrong.
I was so concerned about coming up with ideas and getting them on paper that I didn't pay that much attention to where the ideas were and how organized it was.

3. How I will prevent similar mistakes in the future.
I'm going to make a checklist to use when I revise and proofread my papers. One thing on the checklist will be: Development of Ideas. Another thing will be organization of ideas.

Error Analysis of Research Report

1. What I got wrong and what I should have done.
I lost credit because I did not cite the sources of my information in the text. I should have put the authors' names and publication years at the end of the information I got from them.

2. Why I did this wrong.
In high school we didn't have to do this so I didn't know it was the correct procedure. I didn't understand "plagiarism". I also didn't read the assignment sheet carefully enough to see this was required. I just read it to get a general idea of what was expected and missed some details.

3. How I will prevent similar mistakes in the future.
I'll remember to cite my sources in the text because I'll think about how I would feel if someone took my ideas and didn't give me credit for them.
I'll also read my assignment sheets more carefully, looking for specific details instead of general ideas.

Biology test item

Which of the following is correct for the **resting** membrane potential of a typical neuron?
a) It is negative outside compared to inside.
b) It depends on high permeability of the membrane to sodium and potassium ions.
c) It carries impulses from one region to another.
d). It results from the unequal distribution of ions across the membrane.

Error Analysis of Item
1. What I got wrong and what the right answer is.
I thought the answer was "b", but now I know the answer is "d".

2. Why I got it wrong.
I know there was high permeability to potassium but I forgot it was impermeable to sodium.

3. How I will remember this and prevent future similar mistakes.
I'll remember that the resting potential of a neuron depends upon the **imbalance.** The unequal distribution of ions results from the difference in permeability between sodium and potassium. The membrane is highly permeable to potassium, but it is impermeable to sodium. This causes it to be negative inside compared to the outside.
I'll also try to use the process of elimination more so I can rule out some of the answer choices.