Problem Solving, Reasoning, and Analytical Thinking in a Classroom Environment

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Abstract

Problem solving, reasoning, and analytical thinking are defined and described as teachable repertoires. This paper describes work performed at a school serving special needs children, Morningside Academy, that has resulted in specific procedures developed over the past 15 years. These procedures include modifying "Think Aloud Pair Problem Solving"(after Whimbey & Lochhead, 1991) methods developed for college students so that they can be taught to young learners and by teaching a repertoire of "Fluent Thinking Skills" (Robbins, Layng, & Jackson, 1995) that emphasizes inquiry through questioning.

Keywords

problem solving, reasoning, thinking, Think Aloud Pair Problem Solving, verbal behavior, TAPS

The analysis of learning outcomes (Tiemann & Markle, 1983; 1990) combined with instruction founded on sound design principles (Markle, 1990) empowers educators to teach the most complex of cognitive skills. At Morningside Academy, a small private laboratory school, the faculty fully believes and works toward the radical notion that intelligence can be taught, that intelligence is not static nor determined at birth (see Whimbey, 1975).

Today's Morningside classroom integrates instruction in effective problem solving, reasoning, and analytical thinking, drawing primarily from the investigation of problem solving processes pioneered by Bloom (1950), Dewey (1933), Skinner (1957, 1969), Samson (1975) who credits Albert Upton's methods of 1933, Whimbey (1975), Whimbey and Lochhead (1991), Markle and Droege (1980), Heiman and Slomianko (1988), Robbins, Layng, and Jackson (1995), and Robbins (1996).

That students should be skilled problem solvers, reasoners, and analytical thinkers is not in dispute. Most educators agree that teaching students to be good thinkers is important and that rote memorization, although having value, must augment not replace, the ability to problem solve on one's own. However, there is no consensus about how to teach these skills. A longitudinal study was conducted at McMaster University, by Donald Woods, a professor in the Department of Chemical Engineering, (Woods, 1998) to investigate approaches to teaching problem solving. The study provides evidence that three approaches often used to teach problem solving don't work. To summarize from the McMaster report [italicized text not in original]:

Ineffective approach #1: *Give students open-ended problems to solve.* This approach is ineffective because the students get little feedback about the process steps, they tend to reinforce bad habits, they do not know what processes they should be using and they resort to trying to collect sample solutions and match past memorized sample solutions to new problem situations.

Ineffective approach #2: *Show students how you solve problems by working many problems on the board and handing out many sample solutions.* This, we now see, is ineffective because teachers know too much. Teachers demonstrate "exercise solving". Teachers do not make mistakes; they do not struggle to figure out what the problem really is. They work forwards, not backwards from the goal. They do not demonstrate the "problem solving" process; they demonstrate the "exercise solving" process. If they did demonstrate "problem solving" with all its mistakes and trials, the students would brand the teacher as incompetent. We know; we tried!

Ineffective approach #3: *Have students solve problems on the board; Different students use different approaches to solving problems; what works for one won't work for others.* When we used this method as a research tool, the students reported "we learned nothing to help us solve problems by watching Jim, Sue, and Brad solve those problems!"

Many teachers will recognize these approaches. Whereas the goal of creating good problem solvers seems to be shared by nearly everyone, there is less clarity about how to achieve the goal. However, there are some promising approaches, one of which is the McMaster Problem Solving Program. This program improves the problem solving, reasoning, and analytical thinking skills of college students. Almost all successful approaches (as described by Gustafson and Pederson, 1985, Heimann and Slomianko, 1988; Whimbey and Lochhead, 1991) share two characteristics, 1) they are relatively unknown, and 2) they were developed for high school age students and above. This paper will summarize some of the effective strategies that can help a teacher shape the qualities described by Whimbey and Loch-

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head, and how the author and her colleagues at Morningside Academy and elsewhere, have designed effective programs to teach these vital problem-solving, reasoning, and thinking skills to children much younger than college students.

At any given time, the Morningside Academy population may include students with special needs. Experts in the field of teaching problem solving and thinking skills have remarked that certain procedures are reserved for students of particular intellectual or academic ability level. For example, Beyer (1997) describes one of the limitations of thinking aloud, which many problem solving approaches advocate, stating that thinking aloud may be "difficult for students, especially for younger ones and some of those considered to be academically at risk" (p. 128). Experts in the field of gifted education offer their cautions as well. LeStorti (2000) maintains that developing thinking skills for gifted children presents special challenges. However, Morningside Academy faculty members employ the same instructional and motivational procedures to develop problem solving, reasoning, and thinking skills with all students. We have found that explicit research-based instruction leads to eager, inquisitive, and masterful learners of all ages and levels of achievement. Our school provides a training and observation setting for professionals around the world to witness evidence-based practices.

DEFINITIONS

Skinner's analysis of problem solving (1969, p.133) proposes that, "two stages are easily identified in a typical problem." He describes the first stage of problem solving as, "the situation for which a response has not previously been reinforced, and the second stage as the process of solution, that is, "the behavior which brings about the change is the problem solving and the response to it is the solution." Whereas the stages may be easily identified, Skinner also points out the ubiquitous nature of problem solving. "Since there is probably no behavioral process which is not relevant to the solving of some problem, an exhaustive analysis of techniques would coincide with an analysis of behavior as a whole" (p. 133).

Accordingly, numerous definitions of problem solving have been proposed. In an instructional environment, the *problem solving* to which I refer is defined as a behavioral sequence, in a situation of defined parameters, which leads to a defined outcome as stated by an instructor, within a text, or by the learner. This type of problem solving is to be distinguished from analytical thinking. *Analytical thinking* is a similar behavioral sequence, but involves a further element of inquiry and situations with less well-defined parameters and outcomes. Analytical thinking is necessary when an ambiguous situation requires the learner to identify or create a problem to solve. *Reasoning*, an essential element of both problem solving and analytical thinking, involves the manipulation of verbal stimuli to restrict response alternatives in accord with a problem's outcome. That is, when the environment requires a learner to produce verbal stimuli that sequentially and systematically make one pattern of behavior more likely than another in order to meet a contingency requirement, reasoning is defined. This process is akin to what Skinner (1969) described as an "inspection of reinforcement contingencies" such that behavior can be described that meets contingency requirements without direct contingency shaping or rules. Procedures have been developed that train learners in reasoning and in the inspection of the requirements for reinforcement in most problem solving situations.

THE ROLE OF VERBAL BEHAVIOR

As noted above, one key element of the approach is the production of verbal stimuli that guides the learner through the problem solving sequence, or as more commonly described, the use of thinking or talking aloud during the reasoning process. Although often approached as a skill to be learned, most young children spontaneously engage in these processes when learning something new. Berk (1994), who studied the private speech (audible self-talk), of children in natural settings, reports that private speech "either described or served to direct a child's actions, consistent with the assumption that self-guidance is the central function of private speech." (p. 80.) Summarizing her research with a variety of populations including longitudinal studies of elementary students in a university lab school, low-income Appalachian children, and youth diagnosed with attention-deficit hyperactivity disorder, Berk concludes that, "the evidence as a whole indicates that private speech is a problem-solving tool universally available to children who grow up in rich socially interactive environments" (pp. 82-83). When comparing the Appalachian students in her research to Lawrence Kohlberg's observations of middle-class children, Berk reports an increasing frequency of self-talk for the middle-class children between the ages of four and six which then decelerates during elementary school and becomes inaudible muttering. By age ten, the Appalachian children's private speech is audible 40 percent of the time compared to the middle-class students who spoke aloud only 7 percent of the time. Additional variables occasioning private speech include the task demands, that is, the level of challenge and the social context of the environment.

We, at Morningside, value Berk's suggestion: "The most profitable intervention lies not in viewing private speech as a skill to be trained but rather in creating conditions that help children use private speech effectively" (p. 83). We rely on Skinner's (1953, 1957, 1969) analysis to plan and best arrange such conditions. Once students learn the talk aloud problem solving strategies described below, they are provided with increasingly difficult logic, deduction, analogy, and brain teaser –type problems to reason through. The students are not taught algorithms or "tricks" to solve these problems. Nor are the problems so easy as to have an obvious answer. The type of problem and the conditions under which they are presented are designed to evoke the talk aloud taught strategies since other means of solving the problem are not in the student's repertoire.

Further, one's own description of a performance while it is occurring may have a history of success for any number of reasons. The beginner cook may find himself repeating the written quantity of ingredients aloud while measuring and leveling off the ingredients. "In constructing external stimuli to supplement or replace private changes in his behavior, a man automatically prepares for the transmission of what he has learned. His verbal constructions become public property, as his private discriminations could not. What he says in describing his own successful behavior can be changed into useful instruction" (Skinner, 1969, p. 139). This same instruction when the speaker is his own listener while problem solving may even, at times, be considered a source of automatic reinforcement "where the speaker generates stimuli to supplement other behavior already in his repertoire" (p. 442). That is, the behavior generated by the supplemental verbal behavior may be recognized (discriminated) as providing a solution or a step toward the solution, thus, maintaining the problem solver's behavior (Catania, 1975; Goldiamond, 1976). The question raised is, how do we teach the effective use of supplementary verbal behavior as part of the problem solving process?

Skinner succinctly points out the dilemma of the radical behaviorist who designs instruction that employs sound instructional design principles. "It is because programmed instruction eliminates much problem solving that some objections have been raised against it. The programmer solves the learner's problems for him. How does he do so? What must the instructional designer do if he is either to study or to teach problem solving?"(p. 135).

The analysis began by tackling this problem by searching for practices that exemplify Skinner's analysis. It did not limit the pursuit to those practices that are explicitly based upon Skinner, but instead sought procedures that mirror what Skinner describes. One of the first issues is to create a "natural" environment that will maintain the behaviors we seek to shape without the need for more spurious reinforcers (see Skinner, 1968). Stated otherwise, a culture of thinking needs to be established within the school as a whole. This led to the discovery that a Harvard based research group who investigates problem solving, creativity, and thinking, Project Zero (Tishman, Perkins, & Jay; 1995), had spent a considerable amount of time investigating what it takes to establish such a culture in the classroom. The text, *The Thinking Classroom: Learning and Teaching in a Culture of Thinking* (Tishman, Perkins, & Jay, 1995) provided useful suggestions for our approach. We make sure that a language of thinking is routinely used, that is, questions are not only asked but welcomed. Explicit thinking procedures are taught and their use encouraged, and plans of attack are explicitly made part of the lessons.

Although seemingly contradictory, a direct instruction approach, which provides the teacher with a script and the students with opportunities to respond chorally (as a function of errorless learning; Markle, 1990) or with faultless communication (Englemann & Carnine, 1982), was selected as the most efficient way to create such a culture. For the culture to be established students must be taught how to reason. Thus, the establishment of a highly independent student repertoire, analytical reasoning, is established using a highly structured teacher-dependent lesson. This program is called "TAPS for Teachers" (Robbins, 1996). TAPS is the acronym derived from Whimbey and Lochhead's (1991) paired problem solving, described as Think Aloud Paired Problem Solving." The scripted instruction, TAPS for Teachers (1996) replaces Whimbey's "think-aloud" with "talk-aloud."

But why talk aloud? In everyday practice, "we speak aloud to ourselves upon occasion – for example, when the audible response improves intraverbal chaining. In the solution of a difficult problem, mathematical or otherwise, we resort to overt responses, vocal or written. For the same reason, such covert behavior as counting money or adding figures is likely to become overt in the presence of distracting stimuli" (Skinner, 1957, p. 436). When learners are acquiring a new skill we may even see a greater tendency to disruption by distracting stimuli. Indeed, test designers often include textual "distracters" to separate good problem solvers from bad. Accordingly, to ensure that the problem solving process is occurring, that effective verbal behavior is produced, and that the behavior will not be easily interrupted, a talk aloud protocol is utilized.

TAPS FOR TEACHERS, AN INSTRUCTIONAL PROGRAM

This program is built on the foundation of the speaker as own listener. The power of this dialogue between the speaker and listener in one body, that is, speaker-as –listener, forms the basis of both the TAPS for Teachers and Fluent Thinking Skills lessons. The scripted TAPS lessons introduce the qualities of the two repertoires to be constructed, that of the speaker and that of the listener. Students are paired, with each alternating as speaker and listener as problems are solved. Qualities of the speaker and listener such as voice volume, turn taking, and clear articulation are regarded as component or "tool" skills that facilitate the composite events that occur in the thinking and reasoning classroom and are not taught explicitly with the TAPS for Teachers material.

Whimbey and Lochhead's (1991) system, first called Cognitive Process Instruction, extended Bloom's (1950) work, with the critical difference from Bloom's approach being the partnered dialogue. Without an Active Listener, the Problem Solver's verbalizations or construction of external stimuli goes without reinforcement and support. Eventually, students acquire both repertoires and learn not only to speak, but to listen to themselves and adjust their performance based upon what they hear. TAPS for Teachers teaches students and teachers the qualities needed for each role. Students in the program study the qualities exemplified by each member of this volley. These qualities or repertoires, though based on Whimbey and Lochhead's original profile, have been expanded to include other qualities as a result of errors commonly made by students during developmental testing of the program (after Layng, Stikeleather, & Twyman, 2004; Markle, 1967).

To ensure that students are able to respond along all of the dimensions of a good Problem Solver and Active Listener, the class works through several phases. The first several days of instruction, the teacher leads the class through the scripted instruction. The culture of thinking is built with students making signs and posters using the vocabulary words presented in their workbooks. Cartooned response cards (Narayan et al, 1990) become mnemonic devices to facilitate recall and usage of each quality in the demonstration/observation phase of instruction (see Figure 1). The instructor models a full set of examples and nonexamples of the qualities of the two repertoires with student volunteers rotating as partner to the instructor. Initially, as the class observes the speaker-listener pair, each time the Active

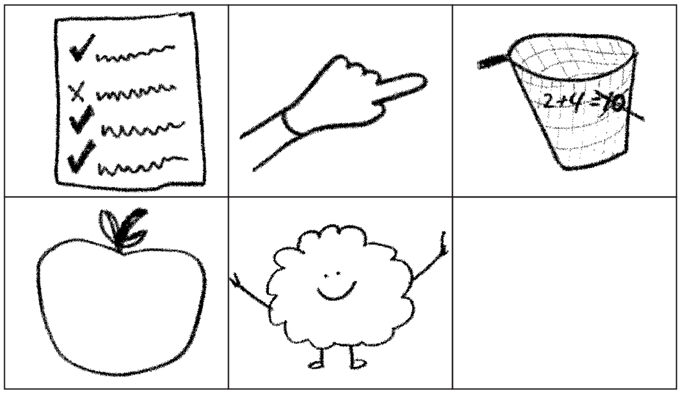


Figure 1. Cartoon side of five double-sided Response Cards: Active Listener Qualities (text appears on reverse) Two-way association practice occurs in partnered practice sessions. ©JK Robbins 2011.

Listener notes the need for the Problem Solver to "check for accuracy" the class holds up the card with the check marks and the X (see Figure 1), signifying that the observers have seen this quality. The use of response cards allows the teacher to note that the group is acquiring the observation skills that will then be required in the next phase of instruction. When the class observes that the Active Listener is closely following along, students hold up the card with the cartooned pointing finger (see Figure 1). The card with the net indicates "catch mistakes"; the card with the apple represents "act like a teacher"; and the warm fuzzy is associated with "use encouraging words." A similar set of cards are used to develop the observer skills as the Problem Solver reasons through a demonstration problem before the whole group. This procedure allows the teacher to see error patterns, to promote engagement, and to count responding. The reasoning process occurs with multiple qualities being demonstrated at once. For example, the Problem Solver may have a "positive attitude" (high subject matter approach tendencies, see Mager, 1997) while "breaking the problem into parts" and thus, both cards could be raised by the classmates.

Students role play and identify both the good qualities and poor qualities of both speaker and listener repertoires. These repertoires include specific domain-free problem attack strategies (see Markle & Droege, 1980), as well as specific prompting strategies employed by the Active Listener to assist the Problem Solver. As the students move to paired problem-solving, the high level of activity required of both members of the pair creates a noisy, productive environment.

One problem confronted by younger learners is a lack of a vocabulary of problem solving. As a result, both speaker (Problem Solver) and listener often exhibit a great deal of hesitation, long pauses, repetition, and disconnected comments. As Skinner (1957, p. 403) describes, when a verbal response is required to "fill an embarrassing pause, we cast for a stimulus." A classic example is chatter about the weather. By teaching the TAPS for Teachers vocabulary to the Problem Solver and Active Listener, the students have access to the words or prompts necessary during those moments when a verbal response is required to provide supplemental support in the problem solving process. By providing a culture of thinking in a classroom that is filled with visual examples of the process being taught, the reasoning process can be shaped, and the learners' "casting about" can be recruited to move the process along.

After the two repertoires are established, the reasoning process proceeds as an interaction of the two repertoires occurring within the "same skin;" that is, the student takes on both roles: Problem Solver and Active Listener. The Problem Solver produces a goal directed dialogue, while the Active Listener evaluates the dialogue for its progress in meeting the problem solving goal. The students have learned to listen to themselves, evaluate their own effort, and provide verbal feedback that prompts further action and eliminates alternatives. One often observes an instance of "self-strengthening" described by Skinner (1957), whereby the speaker-as-listener re-reads directions or reads a problem slowly or reads it in parts until the problem-solving goal is clearly stated. Sometimes the speaker or Problem Solver, is unsure or appears to lack confidence; that is, the learner may emit a weak, hesitant, or incomplete response. The Active Listener, who is the same person as the Problem Solver, may hear the response and add further dialogue, that prompts yet other responses, in a process like that described by Palmer (1991) in his behavioral interpretation of remembering. Stated differently, it is at those moments when the Problem Solver's response is weak, perhaps having forgotten a detail, that the same person as listener will be able to recognize the correct response even though there was a hesitation in its production.

The reasoning process may also make use of a series of formal or thematic prompts (see Markle, 1969; Skinner, 1957); reading the text of the problem aloud again may provide an opportunity to inspect the text for the required information. Students are taught to change the emphasis, to stop at particular words that are key to the meaning – sometimes as simple as the word NOT – (a thematic prompt). The process is not unlike what Skinner (1957, p. 406) describes as "hoping that an intraverbal relation will supply needed information."

We constrain the reinforcement system by initially requiring all taught qualities of the Problem Solver and Active Listener to be present while students complete their logic and analytical reasoning exercises. For example, "Have a positive attitude" is one such quality that may be demonstrated by a student saying, "I can do it. I will solve this problem." Here again, teachers continuously reinforce approach behavior in the context of the Morningside Daily Report Card. A student earns Learning Skills credit for emitting such a response. The Problem Solver and Active Listener repertoires, which are initially rule-governed, become contingency-shaped as the students move through a variety of exercises and then are prompted to "use their TAPS" during basic skills and content class instruction. Students are considered skillful when they can inspect the problem space, describe the requirement that must be met for reinforcement (solution), and produce a self-dialogue (i.e. they reason) which produces the final behavior.

In summary, "Even fragmentary descriptions of contingencies speed the acquisition of effective terminal behavior, help to maintain the behavior over a period of time, and reinstate it when forgotten. Moreover, they generate similar behavior in others not subjected to the contingencies they specify. As a culture evolves, it encourages running comment of this sort and thus prepares its members to solve problems most effectively." (Skinner, 1969, p.143).

TAPS is used to reason through cases of practical deliberation taken from daily life. Dewey described the importance of practicing "practical deliberation" in his book for education majors, *How We Think* (1933). Teachers demonstrate how to apply TAPS to everyday situations, such as how to plan a recess activity. Students are asked to select situations from their own lives for which TAPS might be helpful. Students are encouraged to apply TAPS as they work through everyday challenges such as how to navigate a bus schedule. In the gradual shift from teacher-directed to student-directed learning, students master learning skills using Talk Aloud Problem Solving, which weans them from teacher dependency to independent learning. However, identifying and framing the conditions where TAPS can be most useful ultimately requires an additional repertoire: analytical thinking.

ANALYTICAL THINKING

As noted earlier, analytical thinking is necessary when an ambiguous situation requires the learner to identify or create a problem to solve. It involves the reasoning process described above, but involves a further element of inquiry, often in situations with less well-defined parameters and outcomes. This skill is required when a learner faces an often ill-defined, more global problem. Here's a typical school situation students might face when they realize that a test is coming up: What do I study and how do I know what is important?" Perhaps an assignment is given such as, "Write a persuasive essay that describes why one of two Internet search engines is better." Before one can apply one's reasoning skills, it is critical that there is a clear idea of what it is that needs to be reasoned. Is there a difference in search engine usefulness or does the student need to discuss technical issues; what does the teacher mean by *better*?

Where the problem is not clear, the strategy required is one of inquiry, and to inquire is to question. Questioning combined with reasoning, thus, is the key to analytical thinking. In John Dewey's words (1986, p. 330), "Thinking is inquiry, investigation, turning over, probing or delving into, so as to find something new or to see what is already known in a different light. In short, it is questioning." Even a simple instance of ambiguity, for example, a student reading a novel is confused when the author likens a character to an historical figure. The inquiring reader wonders, questions and now has a problem to solve.

Questions in classroom reading comprehension exercises generally are presented following a prose reading. Students are to "test their understanding" of the text with the questions. Unfortunately, this approach is based on a rather passive view of how one learns from text. The question this approach raises is: at what point is the learner to think analytically about the text? If the learner is answering other people's questions, either posed by a teacher or provided at the end of a text, can the learner really be described as engaging in truly analytical thinking? Based upon Markle's (1990) first principle of instructional programing: "the student learns what the student does" (p.1). Active, meaningful, responding must be verified if we are to ascertain that the activity leads to learning (Cook, 1983; Markle, 1969, 1990). Brethower's (in Heimann & Slomianko, 1985, p.16) observation of successful college students found that they:

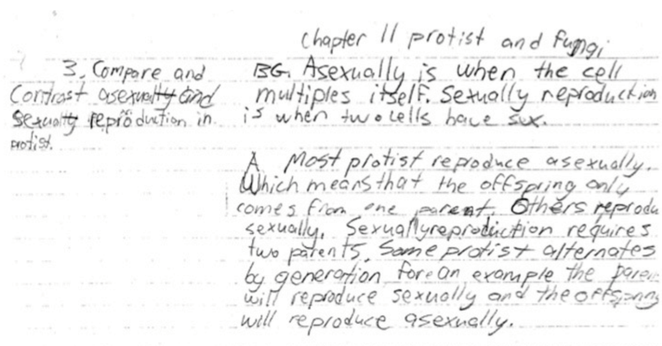
- Ask questions of new materials, engaging in a covert dialogue with the author or listener, forming hypotheses, reading or listening for confirmation;
- Identify the component parts of complex principles and ideas, breaking down major tasks into smaller units;
- Devise informal feedback mechanisms to assess their own progress in learning; and
- Focus on instructional objectives, identifying and directing their study behaviors to meet course objectives.
- Simply reading text cannot be considered active nor does it exemplify meaningful responding. When questions are posed after text is read, students must often reread the text to find the answers and become engaged in the act of answering, rather than being engaged in an act of discovery or inquiry. Conversely, orienting questions, provided by the text or a teacher, and presented prior to the reading task, may serve a different function. They may tap prior knowledge, facilitate recognizing important passages while reading, and provide a basis for feedback as to whether or not the text is understood (Osman & Hannafin, 1994).

Another system of question-generating instruction is derived from the work of Dale Brethower at the University of Michigan in the 1960s who, in turn, refined the SQ3R (Survey, Question, Read Recite, Review) techniques originally designed by Robinson (1946) and revised by Fox (1962). This "Learning To Learn" system (Heiman & Slomianko, 1985) has resulted in significantly improved grades and retention through graduation and is the only college-level program certified by the U.S. Department of Education as producing such gains (LTL site). The Learning to Learn (LTL) system has been further refined by Robbins, Layng, and Jackson (1995) into a program known as *Fluent Thinking Skills*.

Whereas the TAPS procedures prepare students for the final three observations of the four described by Brethower, the first, questioning, must be taught separately and added to the learner's repertoire to produce a true analytical thinker. Teaching students how to question, therefore, has become a central part of the Morningside program. Students learn to question in a variety of contexts and this skill is later combined with the problem solving skills that have been acquired and practiced through our TAPS program.

Several strategies are used to teach questioning. One is based upon the familiar game of 20 questions and is known as the Suchman Inquiry Approach (after Suchman, 1966). After students read or hear a short mystery or puzzling scenario, they generate questions that are answered by the teacher with an answer that is either yes or no. Rudolf Flesch (1951) in "The Art of Clear Thinking" advocates strongly for this exercise, "And that's why, if you're interested in producing ideas, the Greek yes-or-no game is useless, while the game of twenty questions is the ideal model" (p. 112). To shape up better question generating, the students collect all questions generated and rate them after the solution has been attained. This exercise helps students apply a questioning strategy in a non-textual environment.

The primary strategy for teaching analytical thinking in our content courses is the *Fluent Thinking Skills* program. The program consists of a series of systematically designed instructional sequences and practice exercises that teach different types of questioning, and then provides considerable guided practice in



chapter 11 protist and Fungi

3. Compare and Contrast asexually and Sexually reproduction in protist.

BG. Asexually is when the cell multiples itself. Sexually reproduction is when two cells have sex.

A. Most protist reproduce asexually. Which means that the offspring only comes from one parent. Others reproduce sexually. Sexuallyreproduction requires two parents. Some protist alternates by generation for an example the parent will reproduce sexually and the offspring will reproduce asexually.

Figure 2. An example of student questioning to discover the discrepancy between what the student knows versus what is in the text.

their application. Once the questioning skill is firmly in place, students are taught to apply it to textual material they are to learn.

Students are asked to first generate questions to textual material without first fully reading it. They base their questions on the headings, sub-headings, initial sentences in a paragraph, captions, etc. Once the questions are posed, the students are asked to answer them prior to reading the text.

One of the critical features of the *Fluent Thinking Skills* program is that each student must find each discrepancy between the answer to the self-posed question and the response request specified within the text (or lecture material). Figure 2 shows the work of a middle school student using the Fluent Thinking Skills approach with a science text. Each learner creates and identifies a unique discrepancy based upon individual experience. This requirement of self-questioning and finding the discrepancy between what the learner initially calls the "Best Guess" and what the text provides as the answer is labeled, "Not match," and defines what the learner needs to learn. It is the comparison of what the learner knows prior to reading and after reading that defines the discrepancy. The reading-to- answer-questions approach targets exactly that which is missing from the learner's repertoire. Students are encouraged to apply their TAPS skills to first answer their question, and then to resolve the discrepancy.

The production of the student notes in Figure 2 begins in a TAPS partnered environment with the Problem Solver scanning the textbook headings to preview the chapter.

Problem Solver: I see the name of this chapter is Protist and Fungi. The first heading on this page says Reproduction, sexual and asexual.

Active Listener: Yeah, good idea to tie the chapter title with the heading.

Problem Solver: I need to anticipate how the author will talk about reproduction. The words sexual and asexual are almost the same, so it seems like a compare and contrast question will work well. (*Inspecting the problem space*)

Active Listener: Sounds right.

Problem Solver: (writing question in margin) "Compare and contrast asexually and sexually reproduction to protist

Active Listener: Check your question – I don't think it's a complete sentence.

Problem Solver: Oh, I'll cross out the ly. Thanks for following along. And now I'll make my Best Guess.

Active Listener: Nice. Let's see what the book says.

Problem Solver reads passage and identifies that the discrepancy must include the discussion of parent and makes a comparison statement and contrast statement.

Once students have mastered this process, other strategies are added such as using charts and graphs to see relationships in the subject being studied, finding sameness in related concepts, and extending relations to areas outside of what is being studied, among others. What has emerged is a general rule: we learn through discrepancies (cf. Donahoe & Palmer, 1994), and we extend what we know through samenesses (cf. Skinner, 1957).

PROGRESS MONITORING

We employ many explicit strategies in teaching basic skills (reading, writing, mathematics) and content courses (e.g. history, science, cultures and geography) in addition to explicitly teaching reasoning and thinking skills. Given that our school was founded in 1980, with more than 30 years of revising our procedures and instituting annual curricula changes, a discussion of the full Morningside Model of Generative Instruction is beyond the scope of this paper (for an extend discussion see, Johnson and Street, 2004). The most widely referenced methodologies are the use of self-monitoring with a Precision Teaching approach, which builds both confidence and skills as students set and attain personal academic goals, and Direct Instruction (as well as "direct instruction"). Placement in classes with homogeneous grouping and ongoing progress monitoring all contribute to academic gains.

The data collected as students develop their TAPS skills have included duration time to practice and acquire thinking vocabulary words and phrases, as well as time to accurately complete a variety of increasingly complex exercises from "teacher store" workbooks over the course of the school year. We have listed in the Appendix a sample of such material. These data are used to maintain homogeneous groups during the dedicated TAPS instruction. Similarly, the acquisition of Fluent Thinking Skills includes practice and frequency building exercises in discriminating, creating, and answering questions.

Morningside students routinely make vast improvements in their year over year academic performance (Johnson & Street, 1994). Though we do not have data that parses the effects of our various procedures, we can see our learners change from being withdrawn, reluctant, tentative, or careless upon admission to our school, and exhibiting "Subject Matter Unapproach Tendencies" (Mager, 1997), to eager problem solvers who enjoy tackling and solving problems through questioning and reasoning. By directly instructing our learners in these problem solving, analytical thinking, and reasoning repertoires, and by creating a culture of thinking and inquiry, we are demonstrating the power of our behavior analytic to produce learners who will be able to face and solve the rapidly changing problems of the 21st century.

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APPENDIX - RESOURCES FOR TALK ALOUD PROBLEM SOLVING (AGES 4 TO ADULT)

GET YOUR HANDS ON PROBLEM SOLVING

Author: Shirley Hoogeboom & Judy Goodnow
Publisher: Ideal

PUZZLES AND GAMES FOR READING AND MATH (AGES 6-8)

By: Kaye Furlong & Nancy Casolaro
Publisher: Lowell House Juvenile

MATH, BOOK 2 (AGES 4-6)

Author: Martha Cheney
Publisher: Lowell House Juvenile

PUZZLES AND GAMES FOR CRITICAL AND CREATIVE THINKING

Author: Martha Cheney & Diane Bockwoldt
Publisher: Lowell House Juvenile

THINKATHON 1

Author: Charlotte S. Jaffe & Barbara Roberts
Publisher: Educations Impressions

PUZZLES AND GAMES FOR READING AND MATH (AGES 4-6)

Author: Susan Amerikaner & Kaye Furlong
Publisher: Lowell House Juvenile

VENN PERPLEXORS

Author: Evelyn B. Christensen
Publisher: Mindware

SCRATCH YOUR BRAIN WHERE IT ITCHES

Author: Linda Brumbaugh
Publisher: Critical Thinking Books and Software

MATH BRAINTEASERS

Author: April Blakely

Publisher: Good Year Books

PROBLEM SOLVING AND COMPREHENSION

Author: Arthur Whimbey and Jack Lochhead

Publisher: Lawrence Erlbaum Assoc.

BEYOND PROBLEM SOLVING AND COMPREHENSION: AN EXPLORATION OF QUANTITATIVE REASONING

Arthur Whimbey and Jack Lochhead

Publisher: Lawrence Erlbaum Assoc.

ILLUSTRATED MATH DICTIONARY: AN ESSENTIAL STUDENT RESOURCE

Author:Judith de Klerk
Publisher: Good Year Books

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