Second Edition

Thinking Strategies for Science

Grades 5–12

Sally Berman

Hawker Brownlow
EDUCATION

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Introduction

WHY TEACH THINKING SKILLS?

We know that students who possess good thinking skills develop deeper understandings within and across content disciplines and become self-regulated learners (Cognitive Skills Group, 1998). Self-regulated learners take charge of their own learning processes by monitoring the effectiveness of their learning strategies, adjusting learning behaviors that do not seem to be producing desired results, and transferring their learning to new situations (Caine, Caine, McClintic, & Klimek, 2005). In 1991, the SCANS Report emphasized the importance of developing lifelong learning and transfer skills (SCANS, 1991). The United States Department of Labor formed SCANS, the Secretary's Commission on Achieving Necessary Skills, to determine the competencies that workers would need to be successful in the 21st century workplace. The commission identified five competencies:

- Resources of time, money, materials, and skills
- Interpersonal abilities of teamwork, leadership, and respect for diversity
- Information acquisition, organization, interpretation, and transfer
- Systems understanding, monitoring, design, and improvement
- Technology selection, use, application, and troubleshooting

In a 2003 follow-up to the SCANS report, the METIRI group, a company that offers a broad range of consulting services focusing on effective teaching and learning, concluded that globalization and the Internet require individuals to be self-directed learners who can analyze new conditions as they arise, identify, and learn the new skills that dealing with these conditions will require, and independently find a way to deal with the challenges (METIRI Group, 2003). We do students a great disservice if we persist in using traditional "sit and git" instruction.

HOW TO TEACH THINKING SKILLS

So now you may be wondering how to teach students the thinking skills that they need to become self-regulated learners. Weiss (1993) suggests that students need to see that improved thinking skills lead to increased content learning. If students learn how to identify the most important points in a reading selection, for example, they will become more effective at learning by reading. Using graphic organizers appropriately will help students become more strategic learners, encourage them to process information at more complex levels, and by reducing the demands for

semantic information processing, help students with learning disabilities develop deep understanding of content (Ellis, 2004).

One powerful technique that you can use is to model your own thinking processes. As you explain how to solve a problem, describe your thinking out loud. As you give instructions for a hands-on activity, stop to explain why you think the procedure will work. Ask yourself, out loud, "What if this doesn't work?" or "What do I want to learn by doing this?" or "What might be a different way to do this?" Once students have heard your internal dialogue, give them a problem to solve or an issue to discuss and assign roles: one student is to be the Thinker and the other is to be the Prober. The Thinker works through the problem, talking about what he or she is doing, and the Prober asks questions such as "Can you explain what you did there?" or "Why did you decide to take that step?" or "Tell me more about your thinking." This kind of paired thinking helps students become more metacognitive in monitoring the effectiveness of their thinking and their actions.

Many of the activities in this book use graphic organizers that make information more precise, structure the information in useful ways, enhance learning for a wide range of students, and encourage the development of both critical and creative thinking skills and communication skills (Ellis, 2004). Other activities ask students to make careful observations, describe what and how they observed, and ask questions about information that has been presented to them in a variety of ways. As students participate in these activities, they come to a deeper understanding of the content and skills that they are learning while embedding that learning more firmly in their memories (Caine et al., 2005).

What About Students With Special Needs?

Research shows that students with special needs experience success in developing thinking skills when they engage in lessons that explicitly mediate the skills and bridge their use to everyday life examples (Galyam & LeGrange, 2003). Feuerstein (1980) describes mediation as a process by which a more knowledgeable person prompts a less knowledgeable person to label, compare, categorize, and give meaning to a present experience as it relates to prior and future ones. His model of mediated learning incorporates four elements:

- ***reciprocity,*** which establishes a safe-risk connection of acceptance and trust;
- ***intent,*** which focuses attention on the task at hand;
- ***meaning,*** which connects the learning to prior knowledge and places it in the context of appropriate patterns of information; and
- ***transcendence,*** which expands learning into everyday life and promotes transfer (Greenberg, 1996).

In a typical classroom, one teacher would be hard pressed to offer mediated learning experiences to all of the students all of the time, and that is where cooperative learning groups become one of the teacher's most valuable tools.

Here is how cooperative learning aligns with Feuerstein's mediated learning model.

Reciprocity: When cooperative learning is used skillfully, students learn to trust their teammates. They share responsibility for group leadership, functioning, and completion

of an assigned task, and they practice use of social skills like giving encouragement, questioning ideas, contributing a fair share, and taking turns.

Intent: Cooperative group learning involves the completion of an assigned task. Within each group, students perform assigned roles, and each student knows that he or she is expected to contribute to the final group product. The teacher monitors groups as they work and intervenes to correct misunderstandings of content information or instructions. The teacher will often give groups a detailed checklist or rubric that they use to evaluate their progress toward completing the task. Each member of a group knows that he or she may be questioned about the content learning or the process the group is using to complete the task.

Meaning: As teammates work toward completion of the task, the teacher listens to group discussions to check on the accuracy and completeness of content learning. The teacher intervenes if a group has an incorrect understanding of content or skill learning. If a majority of the groups in the class seem to have difficulty with some of the content information, the teacher will take time for whole-class direct instruction followed by group clarification and processing.

Transcendence: At the end of a group activity, individuals process and reflect on their learning and brainstorm ways in which they can transfer their knowledge and skills to new settings. Members of a team share these individual reflections and transfer applications, and the teacher will often lead a whole-class processing session.

Cooperative learning groups become in-class resource groups for special needs students, and their teammates benefit from the cooperative activities by learning leadership and communication skills and, because teaching reveals incomplete or inaccurate knowledge by uncovering misunderstandings, teammates of special needs students improve and deepen their own learning. And as Kluger (2007) reports in his article on how birth order shapes our destinies, the mentoring that students provide to each other in cooperative learning groups can actually raise their scores on IQ tests.

What About English Language Learners?

English language learners benefit from mediated learning and other classroom practices that scaffold their transition as they learn to think in a new language. Students who speak English as a first language often have difficulty keeping up with a fast-paced oral activity, like brainstorming, when no time is given to collect their thoughts. For English speakers and English language learners alike, strategies such as using wait time or think-pair-share slow down the action and provide an opportunity for students to process more deeply and generate a wider variety of ideas. Teachers need to consider what Meyer (2000) calls the "learning load" of a classroom activity and make adaptations that scaffold learning. Tools for organizing thinking that rely on semantic processing help English language learners connect language to content (Beckett & Haley, 2000), and this book features several such tools, including K-W-L, the reading prediction guide, and mind mapping.

The American Federation of Teachers (2002) states that a safe and orderly learning environment is perhaps the most important feature of a classroom in which

English language learners can thrive. Carefully structured cooperative learning activities provide English language learners a safe-risk climate in which to practice and develop fluency in their new language and develop confidence in their language skills (Boothe, 2000). These activities give English as a second language (ESL) students an opportunity to not only speak the language but to hear it spoken by teachers and peers who are competent in their use of English (Brilliant, 2001). ESL teachers have commented to me that cooperative learning teams give their students built-in resource groups that focus on science content learning, and that resource is invaluable to the ESL students as they work to master both the language and the science learning.

HOW TO ASSESS YOUR STUDENTS

One method of assessment, the log, is used throughout this book. Other activity-specific assessment tools are suggested at the end of each activity.

What Is the Log?

It is a record of a student's thoughts and learnings for your class. The log includes focus writing, "Think!" (from think-pair-share), items from cognitive and metacognitive processing, sketches, spontaneous entries, and maybe some class notes.

I asked my students to begin every class session by "logging in," focusing on the prompt: "During our last class meeting, we *did what? Investigated what content? Learned what?*" I told them that the reason for this logging in was to help them connect the new lesson to prior learning, to build on what we had done during our previous class meeting. I also asked them to record unanswered questions they had about the prior learning, and I addressed these concerns for a few minutes before moving into the new lesson.

At the end of each class session, I asked students to "log out" by focusing on the prompt: "Today in class we *did what? Investigated what content? Learned what?* Here is how today's class connects to a part of my life outside of this classroom." I wanted to encourage transfer, and by asking students to make some explicit connection to another class or the everyday world as they logged out, I believe I did facilitate this ability.

Why Ask Students to Keep a Log?

A log helps students keep track of much more than new content learning. At the beginning of a new topic, students may focus by writing down their impressions or thoughts about a key word (i.e., what do they think when they hear *element, gene, ocean*).

As study of the topic proceeds, students are encouraged to jot down clarifications, corrections, and additions to their original impressions or thoughts. The log becomes a record of the progress they have made as they study the topic. At this point, it may include class notes, sketches, diagrams, lists of ideas from "Share" (think-pair-share), or personal goals for making progress in their understanding of the topic. They may write questions that they want to have answered. Encourage them to make their logs a record of their complete experience as they study the topic.

To that end, many of the cognitive and metacognitive discussions that are suggested for activities in this book involve writing or sketching log entries. As students write or draw, they clarify their thinking about the lesson. This helps them remember it better. End of class logging also provides for a quiet time for students to unwind and prepare for the next class or activity.

What Do You Do While They Log?

You log! Model the behavior that you want from them. They will perceive it as being worthwhile if they see you doing it too. The fastest way for you to discourage students' belief in logging is to neglect doing it yourself. I still have my daily log from my last year of teaching, and I treasure it. It gives me a picture of my daily activity and my ongoing metacognitive assessment of myself as a teacher.

What Are the Benefits of Logging?

Students are more focused at the beginning of class. Because you ask them to summarize the previous lesson on the topic, they find it easier to connect information. They have a running record of the development of a topic, which is invaluable when time comes to review.

Students also have fun with their logs. Many of my students recorded personal feelings and thoughts that they found very amusing a few months later. The log can become a diary as well as a record of class work and tool for reflection and improved thinking; it is important that students remember that the log is first and foremost a tool for enhancing their learning and thinking.

Is it Hard to Assess Student Logs?

Not really. Keep in mind that what you are looking for is an indication of clear expression, improved understanding, improved use of thinking skills, and honest reflection. You will soon find that you enjoy assessing logs much more than Scantron tests. They give you the opportunity to witness students' growth and progress from their perspective.

When I was teaching, I worked with five classes a day that each included 25–30 students. A sign on a junkyard helped me find a way to assess that huge number of student logs. The sign read, "GUARD DOG ON DUTY, 3 NITES PER WEEK, U PICK WHICH NITES." I read that sign and I said to myself, "Aha! I can check three log entries per grading period in detail. I do not need to read all 45 log entries for all 130 students. The students don't know that I'm not going to read every entry. I'm the guard dog AND I pick the nights!"

I told the students what I would be doing, and I asked them, "Does that mean you only want to do three complete log entries for each grading period?" They answered that they would still need to do the daily log because they did not know in advance which entries I would decide to read.

Performance-Based Assessments

Specific assessments are suggested for individual activities. Often these are extension performances that give you an opportunity to gather information about your students' use of the targeted thinking skills.

A QUICK LOOK AT SCIENCE INQUIRY

And now you may be wondering how this book aligns with the inquiry-based model of science instruction. Before I answer that question, here's a quick summary of the inquiry-based model.

In inquiry-based lessons, students gather information, question their findings, and investigate phenomena. An inquiry-based activity will include elements that are used in effective scientific investigation. In practice, inquiry-based learning and teaching usually occur along a continuum (Northwest Regional Educational Laboratory, 2007). The different levels of inquiry-based activities represent different degrees of student autonomy; at one end of the spectrum is *structured inquiry* in which students gather information and form conclusions in hands-on activities that are developed by the teacher. The students follow precise instructions, and the teacher leads small groups or the whole class in discussions in which students share conclusions and insights.

The middle ground is represented by *guided inquiry* in which students develop a procedure for investigating a problem or question that the teacher selects. The teacher monitors groups as they plan their investigations and intervenes to keep them on a productive path, and he or she leads small groups or the whole class in an end of activity idea-sharing discussion.

The greatest student autonomy is found in *student-initiated inquiry.* Here students generate an ill-structured question or problem related to a topic that the teacher chooses. Students engage in all aspects of inquiry from developing the question to be answered, to detailing the procedure for an investigation, to collecting and analyzing information, to drawing and sharing conclusions. Students need highly developed critical and creative thinking skills to participate in inquiry at this level.

Each level of inquiry-based learning requires students to possess certain basic cognitive skills. Thinking processes that are integral to scientific inquiry are: observing, classifying, inferring, deducing, making analogies, extrapolating, interpolating, synthesizing, evaluating, and imagining or intuiting (Hassard, 2004). Often, students have not developed these skills because their learning has been a product of the direct-instruction lesson model. This book is designed to help you nurture your students' development of inquiry-based thinking skills. Many of the activities fall into the structured or guided inquiry parts of the spectrum. As you browse through the activities, make special note of the targeted thinking skills and ask yourself why each skill is useful to scientific investigation. Then you'll understand why I believe that as students work in your classroom, it is vital that you *catch them thinking.*