Metacognition in the Elementary Classroom: An Exploration

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METACOGNITION IN THE ELEMENTARY CLASSROOM:
AN EXPLORATION

A Thesis Presented
by
Terri Anne Caffelle

Submitted to the Office of Graduate Studies and Research of the
University of Massachusetts at Boston in partial fulfillment of the requirements for the degree of

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METACOGNITION IN THE ELEMENTARY CLASSROOM: 
AN EXPLORATION

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This thesis is dedicated to my husband Tom, my best friend and life long companion, who supported me and encouraged me every step of the way.

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ABSTRACT

METACOGNITION IN THE ELEMENTARY CLASSROOM:
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Metacognition is a practice which enables students to monitor their thought processes in order to think critically. Research indicates that when students are aware of their thinking they become better thinkers. The purpose of this thesis is to encourage teachers to give more attention to metacognition in the classroom.

A review of the literature on metacognition is given. Next, classroom lessons are outlined which introduce fourth grade students to metacognition in the context of math problem solving. Finally, an initial assessment is given of how students' metacognitive and problem solving abilities have changed as a result of the curriculum.

Before the instruction began, all students were given a math problem solving pretest. A sample of nine students of different ability levels were given a pre-interview to assess their
metacognitive abilities. Based on the pre-interview results, I realized that students were able to metacognitively to some degree, but that it needed to be fine-tuned. Students also demonstrated limited success solving the math word problems.

After five weeks of instruction and practice, I gave a post-interview to the same nine students and the math problem solving posttest to all of the students. I measured the students' metacognitive growth and problem solving growth in several ways.

There was evidence of an increase in student metacognitive and problem solving abilities in several areas, but two areas did not show substantial differences. I feel that one limit of the study was the five week time frame. It should have been extended.

A question surfaced: Are student gains in problem solving ability due to metacognition instruction in the curriculum? Or are they caused by the problem solving instruction itself? A correlation analysis showed that improvement in metacognitive awareness was positively correlated with improvement in math problem solving ability.

A future study was proposed to test the causal connection by comparing problem solving and intellectual gains in classrooms which either use or do not use metacognitive instruction.
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CHAPTER I

INTRODUCTION

Metacognition is a word that is frequently used in thinking skills circles today. Robert Swartz, of the University of Massachusetts, Boston, tells us that:

There is a lot of research that indicates that the more students become aware of the thinking they are doing, the more they learn to think better. Introducing metacognitive techniques into instruction enhances the ability of students to transfer the thinking we are trying to teach to other situations outside of the classroom. How well they do this depends on how much you stress metacognition and what techniques you use when you emphasize it. (1987, p. 1)

This message seems quite logical. If we teach students to be cognizant of their thinking they should become better thinkers and therefore, one would assume, better learners. Furthermore, the level at which students can recognize and benefit from metacognition depends on how much emphasis it is given and the methods by which it is taught.

The purpose of this thesis is to identify components of metacognitive ability that fourth graders are capable of and then to devise and evaluate a curriculum which aims to develop these components of metacognition in solving math word problems. The
The curriculum is presented and then a formative evaluation is done through pre and post clinical interviews.

Chapter II presents a working definition of metacognition and examines expert views about the components of metacognition in solving math word problems. It also explores the recommendations experts make for teaching about metacognition in an effort to develop a framework for a metacognitive curriculum.

Chapter III presents a framework for a five week elementary curriculum which seeks to infuse metacognition into the classroom and describes the kind of in class responses it generated. I begin by considering how to introduce students to different aspects of thinking (including "great thinkers" and attributes of clear explanations of thinking). I move on to suggest ways of creating a classroom environment which is conducive to metacogitating. And finally, I conclude with recommendations for activities which encourage students to practice and improve their metacognitive skills.

Chapter IV provides a preliminary evaluation of the curriculum in the form of an interview study of student metacognitive abilities before and after the classroom intervention. The study was conducted with nine fourth grade students and consisted of pre and
post tests, interviews, and think aloud protocols. The results were analyzed according to Schoenfeld’s (1987) three levels of intellectual behavior (knowledge of one’s own thought processes, self-control and self-regulation, beliefs and intuitions) in order to explore any changes that may have occurred in the students’ thinking. There was also a pre and post test administered to the whole class which was used to assess any changes in their abilities to solve selected math word problems.

Finally, Chapter V provides tentative conclusions about elementary students’ metacognitive capabilities that are relevant to math word problems. It offers suggestions for revisions in the curriculum and proposes additional ways to develop and foster metacognition in the classroom.
WHAT DO THE EXPERTS SAY ABOUT METACOGNITION?

The Components of Metacognition

What is metacognition? Sometimes metacognition is very simply defined as "thinking about thinking". For example, Arthur Costa suggests that "being conscious of our own thinking and problem solving during the act of thinking and problem solving" (1985d, p. 7) would be considered metacognition. Steven Yussen presents a similar definition:

Metacognition, broadly speaking, is identified as that body of knowledge and understanding that reflects on cognition itself. Put another way, metacognition is that mental activity for which other mental states or processes become the object of reflection. Thus, metacognition is sometimes referred to as thoughts about cognition, or thinking about thinking. (1985, p. 253)

Alan Schoenfeld, from the University of California, Berkeley, expands the notion of metacognition, especially metacognition about math word problems, by dividing it into three related but distinct categories. Under each, Schoenfeld has added questions to help us better understand what the category means. The categories are presented as follows:

1. **Your knowledge about your own thought processes.**
   How accurate are you in describing your own thinking?
2. **Control or self-regulation**
   How well do you keep track of what you're doing when (for example) you're solving problems, and how well (if at all) do you use input from those observations to guide your problem solving actions?

3. **Beliefs and intuitions**
   What ideas about mathematics do you bring to your work in mathematics, and how does that shape the way that you do mathematics? (1987, p. 190)

In his third category, Schoenfeld includes students' beliefs about their abilities as they relate to mathematics. This category can also be generalized to include how a students' beliefs and intuitions about their capabilities in any subject can affect how they approach the task. I will explore that issue further in a moment.

John Flavell has been a student of metacognition as it applies to the development of children's capacities to reflect on how their memories work (rather than their capacities to reflect on math word problems). His ideas about the components of metacognition coincide with the first two categories of intellectual behavior suggested by Schoenfeld. He claims that:

"Metacognition" refers to one's knowledge concerning one's cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data.

... Metacognition refers, among other things, to active monitoring and consequent regulation and orchestration
of processes in relation to the cognitive objects on which they bear, usually in the service of some concrete goal or objective. (1976, p. 232)

One of Flavell's key ideas is the notion of "active monitoring and consequent regulation and orchestration of processes" (1981, p. 57). Students must not only become aware of their metacognitive abilities, but also must understand how to use them more productively. In this regard, he thinks of self-regulation abilities as mental skills which are acquired slowly and which through practice become automated and perfected. Flavell's ideas were incorporated into my teaching of metacognition. However, Flavell omits mention of the third component of metacognition suggested by Schoenfeld... one's beliefs and intuitions about his/her abilities vis-a-vis what he/she is pursuing.

Carol S. Dweck (1986) attempted to answer this question by conducting several studies with elementary students. What Dweck and her associates concluded was that there are two distinct ways that students view their intellectual ability. Some view it as fixed, meaning they are born with the ability and it can't be changed (i.e., it is a stable Entity). Others view intelligence as flexible, meaning there is constant change as one acquires new knowledge and skills (i.e., it is Incremental).
According to Dweck, (1986), students who see their ability as a fixed Entity will choose activities that highlight this ability so they will succeed. They will choose performance goals. These students may work hard as long as they perceive themselves to have high ability, but they are often debilitated by making errors which they regard as a sign of failure due to low ability. In contrast, students who feel that their abilities can be changed usually choose activities to challenge and stretch their abilities. They seek learning goals to improve and increase their abilities and are not debilitated by making errors since it is a part of learning.

In subsequent research, Bempechat, London, and Dweck (1991) studied the development of student's thinking about their abilities in different domains: school work, athletic ability, interpersonal ability, and physical appearance. They found that whereas younger (K-2) children had more global conceptions of ability which they applied across domains, by fifth grade students were differentiating among the domains and forming somewhat coherent theories about their abilities within a domain. In my work, I explored students' conceptions of their abilities as thinkers and especially math problem solvers to see if my curriculum changed their thinking in regard to this domain.
Metacognition in the Classroom

What might metacognition look like in the classroom? Arthur Costa proposes that:

Metacognition in the classroom might be characterized by having discussions with students about what is going on inside their head while thinking is occurring; comparing different student's approaches to problem solving and decision making; identifying what is known, what is needed to be known and how to produce that knowledge; or having students think aloud while problem solving. (1985a, p. 21)

All the activities that Costa suggests are centered around having students think about thinking. This was what I wanted my classroom to focus on. It sounds simple, but in order for students to become more aware of metacognition, I needed to provide activities that encouraged just that.

Flavell imagines that in order to foster metacognitive experiences in a classroom teachers should:

...try consciousness raising and training in introspection. Engage children in cognitive enterprises that should produce specifiable metacognitive ideas and feelings. Try to get them to attend to these ideas and feelings. Help them to understand their meanings and implications for subsequent cognitive action. Teach them how to generate metacognitive experiences, as well as respond appropriately to them. Since cognitive monitoring itself consumes attentional resources, we might select as
training settings familiar cognitive enterprises that the child can already manage with relatively little attention. (1981, p.57)

The classroom that Flavell describes is one that is perfectly orchestrated by an instructor who trains, helps, teaches, and responds to students' thinking. This classroom places a value on students' metacognition.

Why is there a need for metacognition instruction in the classroom? Costa explains that:

...Often students follow instructions or perform tasks without questioning why they are doing what they are doing. They seldom question themselves about their own performance. They may have virtually no idea what they are doing when they perform a task and are often unable to explain their strategies in solving problems...

When the teacher clarifies by asking students to explain their answers and how they arrived at them, or to share the rationale behind them, the teacher causes the students to metacogitate. Much evidence suggests that causing students to talk about their thinking processes and problem solving strategies before, during, and after enhances their ability to think. Evidently, thinking and talking about thinking begets more thinking... (1985b, p.134)

A Framework for Organizing a Metacognitive Curriculum

How can I organize my instruction so that it is effective and at the same time accomplishes the goal of infusing metacognition into
the curriculum? I began by utilizing as the underlying structure for
my lessons the three “major practices currently emphasized in
thinking skills instruction” as presented by Robert Swartz (1987, p. 2). Swartz very clearly outlines goals, and strategies for
achieving those goals, which can easily be infused into a teacher’s
daily metacognitive lessons.

The first goal is to teach students to classify their thinking by using specific thinking terms like “predicting”,
“classifying”, “metacogitating”! A teacher should let students know exactly what processes they are using by calling them by the proper names. Silver (1987) agrees with Swartz when he makes the suggestion that teachers focus on meta-level processes in their instruction. Mathematical problem solving behaviors encompass many hidden steps (planning, monitoring, evaluating; etc.). A teacher should highlight these steps for the students, describe the steps used in each process, and label them properly. The modeling of the correct usage of thinking terms by the teachers will encourage the students to properly label these terms, also. The more students think about their thinking and talk about their thinking, the better they will get at thinking, as it will become natural and comfortable for them.
The second goal is to have students describe or analyze their thinking. Teachers need to provide students with a running description of the steps or strategies used in a thinking process. Of course, as mentioned above, teachers must be sure to classify these thinking strategies properly. Swartz, adopting the Lochhead and Whimbey (1982) paired problem solving technique, proposes that teachers invite students to try to think aloud as they solve a problem while a partner records their thought processes.

One technique that can be used to motivate students to analyze their thinking is offered by Schoenfeld (1987). He encourages the use of videotapes in our instruction. By capturing a students' efforts to metacogitate on camera, teachers have the means to go back and analyze student thinking in depth. Students, themselves, will be able to review and critique their work, noting their strengths and weaknesses. The tapes could also be used in the future as a reference for students to utilize when checking for changes in their abilities. It certainly would be a valuable tool for both the teacher and student to work with.

Collins and Brown (in press) propose three additional techniques which support the goal suggested by Swartz (helping students to describe and analyze their thinking). They suggest that teachers include inquiry, articulation, and reflection in their
repertoire of teaching strategies. Inquiry is a strategy of questioning students to lead them to articulate and refine "proto-theories" about knowledge. An example of a time when the inquiry strategy would be useful to use in metacognitive instruction is when the teacher and students are comparing several strategies presented to solve one word problem. In this situation, the teacher would systematically question the students about why one strategy was good while another was poor, to get them to formulate explicit models of what a good strategy looks like in reference to this type of problem. So the teacher's questions become as important in effective teaching as the students' responses.

Articulation is the second technique endorsed by Collins and Brown. It includes any method of getting students to articulate their knowledge, reasoning, or problem solving processes. Inquiry teaching, as described above, is one method of accomplishing this task, but there certainly are others. Having students try to solve think aloud word problems would invite them to articulate their thought processes as they occurred. Having other students critique their descriptions would also enhance this method of learning. Focusing on the preciseness of their language should assist students in fine-tuning their articulation skills and therefore have a better understanding of their thinking processes.
The third teaching method put forth by Collins and Brown is reflection. This strategy involves replaying for students the process by which they performed a task. Having this available allows the students to then compare their method with one used by an expert, revise their strategies as necessary, and get a clearer picture of their thinking processes. The use of this strategy in metacognitive instruction might include videotaping a student as he/she solves a problem, as suggested earlier by Schoenfeld. Alternatively, a tape recorder could be just as valuable in documenting a student’s thought processes. Indeed, some teachers might feel more confident in using a tape recorder as opposed to a camcorder.

The third major goal that Swartz (1987) suggests is recommending and prescribing ways of thinking to our students. He feels that it is important for teachers to prescribe effective ways for students to think through issues. He also asserts that teachers will be successful in accomplishing this goal if they ask students to develop rules for good thinking, recommend ways to think to others, plan thinking projects, and correct ineffective thinking.

Edward Silver (1987) includes situational problem solving as a strategy for prescribing ways of thinking. He points out that
teachers need to provide students with prototypical problem situations when introducing and instructing in mathematical concepts and skills. Having these prototypical problems outlined and detailed should allow students to apply this acquired knowledge to similar situations when they encounter them in the future. This would facilitate the solving of math problems by taking some of the thinking out of them. When students read a problem and determine that it is a 1-step addition problem, for example, then they will know that they should follow the rules for solving a 1-step addition problem as prescribed by the prototypical problem.

Collins and Brown (in press) suggest two additional strategies that I believe could enrich instruction regarding the third goal that Swartz presents to us. They recommend that coaching and exploration be practiced in the classroom. Coaching consists of observing students carrying out a task and then giving them feedback as the teacher diagnoses their areas of weakness. In metacognitive instruction this could be carried out by analyzing a students’ description of their thinking processes as they solved a word problem. You would then provide them with information about the strengths and weaknesses of their metacognitive skills, as well as prescribe a plan of action for the student which will foster growth in their abilities.
Exploration, as Collins and Brown (in press) report, involves pushing students into a mode of trying to learn how to do an activity better on their own. The implications for metacognitive instruction are great. For example, after students have received a diagnosis of their areas of weakness, the teacher could ask them to develop a plan to advance those skills. This forces them to analyze their thinking and to explore possible techniques to use which best address these weaknesses. By experimenting with different techniques and strategies, which they have created themselves, the students learn more as the material becomes their own.

Another technique which was mentioned by several of these experts and supports all of the goals proposed by Swartz is modeling. This involves showing students how an expert does the task, while explaining the reasons why it was done that way. In order to incorporate these processes into their repertoire, the students need to see the processes utilized and hear them explained. The more students see techniques and strategies about metacognition being used, the more familiar they will become with them and they will be more apt to use them (and use them correctly).

An overarching concern, referred to in much of the research, is the set-up of the classroom during metacognitive instruction. Schoenfeld (1987) suggests designing whole class discussions of
problems when introducing new strategies or when the teacher is modeling a desired behavior. Whole class discussions are also appropriate after students have worked in small groups. It is then valuable to have them reconvene and share their ideas. But many of the experts agree that the students benefit the most by working in small groups. Cooperative learning increases the students' participation and enhances the quality of their work. So much of our work in metacognitive instruction is conducted in small group settings.

Many of the techniques proposed by Swartz, Silver, Schoenfeld, Collins and Brown have been incorporated into the lessons and activities presented in Chapter III. Their suggestions seemed quite manageable and were interwoven in my classroom lessons. These lessons were designed to focus on metacognition and problem solving in math word problems. However, I found that the techniques and methods described could easily be transferred to other subject areas (and should be).

Age and Metacognition

How able are children to engage in metacognition? Ann Brown indicates in her discussion of metacognitive processes that "it has been assumed that these activities are not necessarily statable, somewhat unstable, and relatively age independent, that is, task and
situation dependent" (1978, p. 79). Also, on the subject of age and its relationship to metacognition, Flavell writes:

We would expect an increase with age in the tendency for cognitive goals to call up relevant segments of metacognitive knowledge. The most obvious reason is the undoubted increase with age in the sheer amount of such knowledge that has been acquired and stored. A more interesting possibility is that whatever knowledge is available in the younger child's memory has been less well learned, organized, generalized, etc., and is therefore less accessible. The older child may have more and better retrieval routes from specific cognitive goals to appropriate metacognitive knowledge. A related possibility is that the older child may have learned to make a deliberate search of his metacognitive knowledge base when establishing and pursuing a cognitive goal. (1981, pp.42-43)

However, there is also ample evidence from Flavell and Brown's work that even young children are able to reflect on some aspects of their thinking. Indeed as Brown asserts, the level of a student's metacognitive processes is often dependent upon the task, situation, and his/her knowledge of these skills. Therefore the activities in Chapter III were designed to encourage students to begin to contemplate their own math metacognitive abilities and those of others. An interesting question to be addressed in this research is the extent to which fourth graders of all ability levels are able to reflect on their math problem solving abilities and the extent to which they can improve these abilities in a five week curriculum. I attempt to answer this question in Chapter IV.
How would I invite students to think about their thinking? I certainly would not introduce the term “metacognition” to elementary students with Schoenfeld’s full definition. But it is a term that students can become comfortable with. I recognized the need to start young children off slowly, by systematically introducing new concepts which build upon one another. Robert Swartz supports this notion by telling teachers that they:

... should not feel that they have to try to achieve the ultimate goal of metacognition all at once. Rather, we can build our students’ capabilities at monitoring and directing their thinking by stressing one or another component of metacognition in a systematic way until students have developed the full capability to do this. (1987, p.1)

Thus, I began introducing metacognition to the students gradually. I encouraged them to think first about the thinking of others and then to consider their own thinking. It seemed to me that initially, it would be difficult for students to talk about their own thinking abilities since this topic was unfamiliar to most of them. I felt it was better to remove them from it one step and begin
discussing others first. My strategy fared well as the students spoke about the thinking capabilities of others quite freely. They were able to easily generate numerous ideas about thinking. Would it have worked as well if I had the students begin thinking about themselves first? I am not sure. It would be interesting to try this again with another class and compare the responses.

The following activities focused on some basic questions which I felt would help introduce my students to metacognition. The class brainstormed responses in small groups, then reconvened to share ideas.

- **Great thinkers.** The first question that I asked students to contemplate was: Can you name some great thinkers? The responses to this question were typical of what you might expect young children to say. Our list of great thinkers included Mom, Dad, and the teacher (of course). The list continued by mentioning former teachers, the principal, older siblings, and many famous people (George Washington, Thomas Edison, the President, etc.). There were really no surprises on the list. It was comprised of people the children admired or considered to be smart, famous, or important.

- Once the students felt their list was complete we hung it in the classroom and left it there. Students were invited to add other
names of great thinkers to this list as they came up with them. I was hoping that at some point the students would feel confident enough in their abilities as a great thinker to add their own name to our list. This was what I was striving for!

Attributes of a great thinker. My next step in the introduction process was to ask students: Why would someone be considered a great thinker? What makes a person a great thinker? What are the attributes of a great thinker? I asked these questions to help students to get in touch with their thoughts on what makes someone a great thinker. They obviously knew many people who they felt were great thinkers (we need only to survey the extensive list which they generated on this subject to see that). Now what I wanted to find out was why they considered these people to be great thinkers? What enabled these folks to be included on our chart? It was my hope that students would focus on their ideas of what makes someone a great thinker and realize that they too could be a great thinker if they were willing to learn how.

One example of a creative thinking activity, which would be fun to try, is to have students design a poster depicting their perception of a “great thinker”. On this poster they would include a list of characteristics. The goal of the assignment would be to determine if the students’ perception of a “great thinker” had
changed during the school year. This change could be measured by having students do the same activity at the end of the year and comparing the results. Although I did not use this lesson, I suspect the outcome would have been revealing.

**Reasons for thinking about thinking.** Now, I began to zero in on the students' thinking itself by asking the following questions: Have you ever thought about your own thinking? When did you think about it? Why might it be important for you to think about your own thinking? I moved away from having them discuss the thinking of others toward having them focus on their own thinking.

The above questions could be used in a class brainstorming exercise as well as in small group discussions. We brainstormed responses as a class. I encouraged them to share examples from their own personal experiences. I felt it would help them later in other exercises. I kept a list of the ideas that were gathered for future use. A comical, but insightful, response that one of my students offered was that he thinks about his thinking when he gets into trouble. When he does something wrong, he asks himself, "Now why did I do that?"

**Feelings about thinking.** In this exercise, I asked students to share their opinions about thinking in general by asking them to
complete the following: Thinking.... My goal was to uncover some of their initial biases on the subject. Although they seemed to have some preconceived notions about it, I found that thinking was a topic that was largely unfamiliar to most students. The most popular misconception was that you have to be very smart to be able to think.

I had students complete this activity both before and after learning about metacognition. Most of their initial responses had a negative undertone; students seemed to perceive thinking as a chore. Some of their responses which exemplified this perception were: Thinking... "makes you tired, gives you a headache, makes your eyes hurt, makes you hungry, makes you hot, makes you sleepy, makes you wish you were home, makes you feel emotions (like sad and mad), makes you bored, and is dangerous." There were a few positive student responses: Thinking... "makes you smart, makes you wonder, gives you something to do, makes you think of things, makes you daydream."

At the end of five weeks of metacognitive instruction, I asked the students to try this activity again. This time the chart they created was quite a bit more positive than the earlier version. The majority of students now felt that thinking: “strains your brains, is fun, makes me smart, makes me organized, makes me happy, is easy,
makes you metacogitate, gives you ideas, makes you feel good." I feel that the more positive responses indicate that the curriculum was effective in dispelling some of the students' faulty notions about thinking by familiarizing them with it.

**Introducing Metacognition**

Once students had been eased into thinking about thinking, I felt it was time to introduce the term metacognition. The simplest and most direct definition is thinking about thinking. Metacognition is thinking about your own and others' thinking. This is the definition I used initially.

I found it was beneficial to refer to the brainstormed list of ideas which had students describe times when they thought about their own thinking (Reasons for Thinking About Thinking). I explained to them that they were using metacognition in this exercise. This explanation helped students to relate the concept of metacognition to actual usage. I was surprised to see how excited students became when they discovered that they had unknowingly used metacognition.

**Precision in language.** The second important aspect of metacognition that I wanted students to grasp is that metacognition involves not only thinking about their thinking, but having the ability
to describe their thinking clearly to someone else. According to Sternberg and Wagner:

Some people are unaware of their own thinking processes. They are unable to describe the steps or strategies they use during problem solving, cannot transform into words the visual images held in their minds, and seldom evaluate the quality of their own thinking skills.

We can determine that students are becoming more aware of their own thinking as they are able to describe what goes on in their heads when they think. When asked, they can list the steps and tell where they are in the sequence of a problem-solving strategy. They can trace the pathways and blind alleys they took on the road to the solution, and describe what data are needed and their plans for producing those data. (1980, 289)

I agree that in order to become better thinkers students need to be able to understand and to translate into words their thought processes. The more clear their descriptions are, the better they and others will understand their thinking and be able to learn from it. Students must be made aware of the fact that describing their thinking clearly and concisely is just as important as being conscious of it.

Arthur Costa confirms this belief by presenting us with the concept of using a student's precise language as a tool to measure the growth in their thinking processes. He clarifies his perception of precise language by writing:

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Some students' language is confused, vague, or imprecise. They describe attributes of objects or events with nonspecific words such as "weird, nice, okay." Objects are referred to as "stuff, junk, things." And sentences are often punctuated with "ya know, er, um."

As students' language becomes more precise, they use more descriptive words to distinguish attributes. They use correct names and, when universal labels are unavailable, they use analogies such as "crescent-shaped" or "like a bowtie." They speak in complete sentences, voluntarily provide supportive evidence for their ideas, elaborate, clarify, and operationally define their terminology. Their speech becomes more concise, descriptive, and coherent. (1985c, p. 290)

My goal was to have students follow the thoughtful steps described by Sternberg and Wagner as well as to introduce the idea of striving for precision in language. I began by asking students to discuss the following question: Why is it important to be able to clearly describe your thoughts to someone else? In asking this question, I was encouraging the students to think about times when they would need to explain something clearly to others (e.g. when giving directions on how to get to a certain place, when explaining how to play a game, or use a toy, etc.).

We also talked about why it would be important to be clear in our explanations and we kept a record of the ideas gathered. Some of the student responses included: "they wouldn't understand you, someone wouldn't be able to play a game with you if they didn't
understand how to play, they might get lost if you gave bad
directions, they might cook something that tasted awful if they
couldn't follow your directions, and they would get their math
problems wrong if you didn't explain how to do them clearly enough."

**Evaluating clear and unclear language.** Next I wanted students
to know what was meant by a clear explanation of thinking. I
wanted them to begin to notice the differences between good, clear
descriptions of their thinking and the opposite. So I gave the
students examples of two different explanations of thinking. I asked
them to label which was an unclear explanation of thinking and
which was a clear explanation of thinking. I designed a worksheet to
be used in this exercise (see Appendix A).

The students viewed the worksheets independently, labeling
the examples as either clear or unclear thinking. Then I tallied their
votes. I did not indicate to the students which I thought were clear
and unclear explanations, but let the students decide. I felt that the
thinking process they used to make their decision would help to
prepare them for the next activity.

**Attributes of precise language.** Next, I wanted the students to
describe the attributes of a clear explanation of thinking and an
unclear explanation of thinking. I asked them to look at the tally
sheet from the last activity. All of the students had responded correctly. I pointed out that they were indeed able to distinguish between clear and unclear explanations of thinking.

In the next step, I endeavored to draw from them what criteria they had used to determine the label for each. To accomplish this, I took the examples from the worksheet separately and had the students work in small groups to define the attributes for each type of thinking. I encouraged them to be precise with their language when describing these attributes. Also, I reminded them that they would need to reflect on the thoughts they had as they chose the categories. What made them decide whether it was a clear explanation of thinking or not? I pointed out to them that they would be using metacognition when completing this task.

After brainstorming, I invited the groups to share their ideas with the class. I recorded the attributes of clear thinking offered by each group as follows:

**Attributes of a Clear Explanation of Thinking**

- it's clear
- you can understand it better (than an unclear explanation)
- told you more
- gave more specific information
- listed everything
- went in order of how the person thought
- told how he thought and what he did
- good
- you could do what he did by reading it
organized
gave details
it's better to read than the unclear explanation
it's easier to read than the unclear explanation
nice
has more words
clearer words
good thinking

We examined these attributes by discussing each and noting the differences. In our discussion we determined that each of the attributes could be placed under one of three descriptive categories:

1. uses precise language (exact words, specific details)
2. is sequential (describes events in order)
3. is complete (tells everything)

Consequently, our list of attributes was transformed into a guide for determining the clarity of an explanation of thinking. It was entitled A Clear Explanation of Thinking and was transferred to chart paper and prominently displayed in the classroom for students to use as a reference.

At this point, students had engaged in metacognitive activities that encouraged them to think about their own and other's thinking. They had also been made aware of the importance of good, clear descriptions of thinking by contrasting them with unclear thinking explanations. Having provided this framework for the use of metacognition in the classroom, it was now time to introduce ways
of practicing this skill and following its development in students in a supportive classroom climate.

**Developing a Supportive Classroom Climate**

One of the most important things to remember is that the promotion of metacognition in the classroom should be fun. It should not be something scary that is drilled into the students. Allan Glatthorn and Jonathan Baron remind us that:

*Our goal as educators is to foster the development of the "good thinker" attributes while helping students understand the limitations of contrary dispositions and behaviors. One fundamental approach is to provide a classroom climate conducive to and supportive of the attributes of good thinking.* (1985, p. 52)

As Glatthorn and Baron say, the atmosphere in the classroom should be one that invites the students to use their metacognitive skills daily until they become second nature. The following are some suggestions of activities which I used to create an atmosphere conducive to metacogitating.

**Journals.** Each member of the class, including the teacher, kept a written record of at least one time that they used metacognition each day. A Metacognition Journal is a valuable tool for students to use to assist in record keeping. Joan Boykoff Baron and Bena Kallick praise the value of journals by saying:
... Journals are a rich source of data about what takes place during a particular lesson, and time should be set aside to allow students to reflect on their thinking. Systematic observations over time are necessary to provide a sufficient lens for understanding and evaluating thinking. (1985, p. 285)

I set aside ten minutes before lunch each day for the children to write in their metacognition journals. Of course they were free to make entries on their own, but having a specific time each day helped those students who were not doing it automatically. If everyday seems like too much at first, then a teacher could start students off keeping track of at least one time each week that they metacogitated, then two times each week, etc. Gradually, the teacher could increase until students are keeping a daily account of at least some of their metacognitive activity.

At the end of each day or at some designated time during the week, students should have a chance to share their journal entries. We shared on Friday afternoons unless someone had a "really good share" (as the students called it) that could not wait until Friday! Discussing examples of metacognition being used in various ways should help to promote the transfer of this skill to new areas for students who may be stuck using metacognition in only one subject. Instructors should also use this time to share their metacognitive
moments, to provide some of the modeling which Schoenfeld and others have suggested.

At first, many of my students focused on examples of metacognition in math. I assumed this was because we began learning about metacognition with math word problems and they felt comfortable with it. During sharing sessions I made a point of highlighting examples that students gave in areas other than math so that classmates would begin to transfer the use of metacognition to other subjects or situations.

**Signs.** Another tool that I used to create a classroom atmosphere conducive to the use of metacognition were brightly colored signs. These signs were prominently displayed around the room to serve as memory aids encouraging the students to use metacognition frequently. Some of these signs simply read: Did you metacogitate today?

Students were also encouraged to use their metacognitive skills outside of school to provide other opportunities for the transfer of these skills to take place. They received a personalized sign which asked: Did I metacogitate today? It was sent home for students to hang in their room. The students loved bringing these signs home and explaining this word to their parents!
The children were encouraged to design their own signs referring to metacognition. They were very creative and came up with wonderfully bright posters which were hung around the room and in the hallway outside of the room. Having the signs in the hallway brought much attention to our classroom as people wondered what in the world metacognition was! This provided additional opportunities for the students to focus on metacognition by explaining it to others. It was also fun for the students as it seemed to make them feel very important!

A class contest. I also had the students keep track of the times they heard themselves or others use metacognition in the classroom. Each time someone was noticed using metacognition (in a group or in front of the whole class), I pointed out how and why metacognition was being used. I then asked the student to record his/her name on a chart which tabulated the class metacognitive activity.

At the end of the week we counted up the number of times that metacognition was used in the classroom. I encouraged the students to try to increase this number the following week. At the end of the month, if their use of metacognition had grown, I would reward them with something special (free recess, art project, no homework, picnic lunch outside, etc.).

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I found that the students needed a lot of coaching in the beginning. It was not always easy for them to be able to identify that someone was using metacognition. I was constantly on the lookout for instances of student metacognition to highlight. We always seemed to be talking about it. Eventually, the students became better at noticing classmates using metacognition. They began to listen differently, always ready to say, "He metacogitated!"

**Practice Makes Perfect**

Students not only need an environment which fosters metacognition, but they also need an environment that structures opportunities for them to practice the skill in specific areas. In my curriculum I chose to focus on metacognition being used in math word problems. I developed four activities which engaged students in the practice of metacognition in the classroom.

**Thinking problems.** Students were assigned thinking problems for homework. These thinking problems were simple math word problems. In order to complete the assignment, students had to come up with a solution to the problem as well as an explanation of how they arrived at their answer. They needed to be prepared to clearly describe their thinking process to the class.
Prior to the discussion of student solutions, I would model my metacognitive activity by explaining the thinking process I used to arrive at my answer. Schoenfeld (1985) used this technique when teaching problem solving. Collins and Brown supported Schoenfeld's modeling techniques and explained how he used them by writing:

First, he models the selection and use of different heuristics in solving problems for which their use is particularly salient. In this modeling, he is exhibiting the thinking processes that go on in an expert problem solver.

Next he gives the class problems to solve that lend themselves to the use of the heuristics he has introduced. During the problem solving, he acts as a moderator, soliciting heuristics and modeling the use of control strategies.

The third kind of modeling is initiated by a challenge he makes to the students to find difficult problems for him to solve. Occasionally the problems are hard enough that the students see him flounder in the face of real difficulties.

Seeing how experts deal with problems that are difficult for them can also be critical to students' ability to develop a belief in their own capabilities. Even experts stumble, flounder, and abandon their search for a solution until another time. Witnessing these struggles helps students realize that thrashing is neither unique to them nor a sign of incompetence. (in press, 8-9)

**Modeling.** As previously stated, I modeled my thinking first until I felt the students were comfortable with the practice of describing their own. At that point I became the moderator, as
Schoenfeld did. I did not, however, invite the students to find difficult problems for me to solve in front of them. This activity would call for a think aloud solution as used in my student pre and post interviews (described in Chapter IV). I think this is a marvelous idea that I will definitely use in the future!

**List thinking steps.** I encouraged students to jot down notes to help remind them of their thinking processes. I felt it was important to have students transcribe their thinking as they went along to aid the development of greater accuracy in their descriptions. I encouraged this throughout the *five weeks of* metacognition instruction. However, this technique may be dropped when the teacher feels that the students are familiar with using metacognition. Eventually, we are looking for students to be able to verbalize their thinking processes automatically.

Another benefit of having students write down their thinking processes is that they will be able to understand them more clearly and make revisions if necessary. Many times, after listening to the teacher or classmates describe their thinking, my students realized that their descriptions were incomplete. They knew that they had used the same (or a similar) step but had not written it down. But that was okay! By modifying their written responses, students were monitoring their thinking processes and therefore utilizing
metacognition. They were constantly being reminded of this in a positive manner and were therefore confident when making revisions.

Having students write down and then verbalize their thinking processes also allowed those who had not solved the problem correctly or efficiently to adopt someone else’s method to be used the next time a similar problem arose. This practice encouraged the expansion of the students’ repertoire of problem solving strategies and fostered metacognition skills.

Feedback. At the end of the discussion of a thinking problem, students commented on the effectiveness and clarity of the explanations given. We referred to the chart which described a clear explanation of thinking and noted how it related to the presentations. We discussed why some strategies were more effective than others. At first, the assessments were general so students didn’t feel intimidated and unsuccessful about their presentations. A response like, “Your description was fuzzy. I couldn’t follow it,” was quite common in the beginning. I would then have to step in and ask questions to clarify their response (e.g. “What exactly did you not understand? Can you give us one example? Why do you think that you did not understand it? Do you have some suggestions for improvements?”). This process also
benefited the development of precise language among the students as they were asked to add detail to their opinions.

Gradually, student comments about presentations became clearer and more concise. It was common to hear, “Why did you use A instead of B? Could you tell me why you multiplied instead of adding? Wasn’t that the long way of doing it?”

At first, I did most of the critiquing myself which allowed me to focus the discussions on the skill of self-regulation as well as precision of language. When students shared their solutions we discussed which were most efficient and why, which were least efficient and why, which were new, as well as which solutions had been used before. Soon I began to hear the students asking themselves and others these same questions indicating development in their self-control and self-regulation skills. I feel that the questions I posed, and the reactions to student presentations that I modeled, promoted the types of responses previously mentioned. Eventually, I slid into the facilitator role as the students took more initiative in directing the discussions.

As students felt more comfortable with the metacognitive process I progressed to the next stage of assessment. This stage provided students with specific written recommendations about their metacognitive verbalizations to be used as a tool to promote
growth in their abilities. The students moved from general verbal assessments to specific written assessments. Students were coached on their individual abilities to metacogitate by their peers, their teacher, and themselves.

At the end of a student's presentation he/she was provided with written critiques by the teacher and classmates. I asked that at least one positive comment about the student's presentation along with another noting an area needing improvement be included on the response sheet. This sheet was also to include suggestions for ways to improve. The presenting student then gathered these response sheets and reviewed them to identify his/her strengths as well as weaknesses (see Appendix C for a sample student response sheet).

After having identified these areas, the student then designed a plan to try and improve any weaknesses. Working cooperatively to create an improvement plan worked quite well with my students. The plans developed cooperatively were much more complete than those developed individually. The differences can be noted in the two sample improvement plans represented in Appendix D.

Schoenfeld (1985) explains that work done by Petitto gives us insight into the reasons why tasks completed cooperatively are often better than those completed individually. He reveals that:
Often the way that a pair of students approach an estimation task differs qualitatively from the approach taken by either student alone. The new approach evolves during the solution as a result of interactions between the two students. Once it emerges, it can become part of the individual students' repertoire. Thus social interactions spur individual cognitive development. (1985, p. 142)

Research indicates that the pairing of students with different abilities becomes quite important when trying to further their cognitive growth. Experiments have been conducted which explored the causes of cognitive growth. Results have indicated that more progress takes place when children with different cognitive strategies work together than when children with the same strategies do so, and that not only the less advanced but also the more advanced child makes progress when they interact with each other.

Vygotsky (1978) agrees with the idea of pairing students with different abilities to produce the most results when he writes:

Working as an individual, a child may perform up to a certain intellectual level. Working under adult guidance or in collaboration with more capable peers, the student may perform at a somewhat higher level. The range of skills that extends beyond what the student can currently perform, but that the student can perform with assistance, is the ZPD (zone of proximal development) (1978, p. 58).
I attempted to pair students with different metacognitive abilities as often as possible to stimulate student performance in the ZPD. The plans created by my students were very simple, but I feel appropriate for nine-year-olds. They typically included the naming of an area needing improvement and one strategy that the child could use to try and modify this weakness (as shown in the Individual Improvement Plan, or IIP displayed in Appendix D).

When the IIP was completed it was shared with the teacher or other classmates for further suggestions. When discussing his/her plan the student was encouraged to explain how it was created. This offered the students another opportunity to utilize their metacognitive skills.

Schoenfeld's suggestion of the use of a videotape to improve students' metacognitive abilities would seem to fit quite well at this time. Students having difficulties, or those who are interested in improving their metacognitive skills, could be taped as they solved a think aloud word problem. They could review the tape individually or with others to critique their efforts. Having the tape available to examine may also help them in fine-tuning their individual improvement plans.

I never videotaped my fourth grade students using metacognition, but I did set up a learning center which gave them
the opportunity to audiotape themselves solving a think aloud word problem. The center contained our class chart which described A **Clear Explanation of Thinking**, a stack of word problem cards, paper, pencil, a tape recorder, and headphones.

The students began their time at the center by reviewing our class chart. This was to remind them of the criteria used to determine a clear explanation of thinking. Next, they chose a word problem card, turned on the tape recorder and began to solve the problem aloud. When they finished, they played back the tape and listened to themselves solve the problem. The paper and pencil was for taking notes about their thinking process. The students kept a record of what they did well and noted areas needing improvement. Finally, they retaped themselves solving the same problem again, making the necessary adjustments. Usually, two students worked together at the center.

An added dimension to the learning center activity, that would be quite beneficial to the students, would be to transcribe what they recorded and give them a copy of it. Students would then be able to study, at length, exactly what they said, what they did not say, and what they really meant to say! Transcribing these would be a long and time consuming process. This may be a good way to use parent volunteers. Let them transcribe the tapes for you. However you do
it, this would be an excellent activity to further assist the growth of student cognitive abilities.

**Thinking and Great Thinkers**

After five weeks of metacognition immersion, it was time to reflect on what we had done and to look for any changes in the students’ original thoughts about thinking and great thinkers. I again asked the students to share their perceptions of thinking by completing the following: Thinking... The purpose of repeating this exercise was to look for any changes in students’ opinions which may have occurred. The responses, as discussed earlier, were very positive in comparison to our first attempt at this exercise. It would seem that thinking was not as horrible as one might have thought after reading the students’ initial opinions.

Next, I was interested in finding out what the children presently felt made someone a great thinker. Earlier, the students’ perceived that being smart, inventing something, or being famous was about all that was necessary to be considered a great thinker. Was this still their belief? No! I was thrilled to discover that the children now felt that there was more to being a great thinker than being smart! A great thinker needed also to take their time, think carefully, metacogitate, work slowly, check their work, etc. Even though someone mentioned being smart as an attribute of a great
thinker this time also, I was pleased to discover that the majority of responses were identical to the ones we stressed in our lessons on metacognition. It seemed that the students now perceived that being a good thinker was connected to their actions, not their ability!

One of the most exciting results of my endeavor to teach students about metacognition was that several of my students gained enough confidence to place themselves on the list of great thinkers! This occurred after the study had been completed and I asked the class if anyone felt that they were a great thinker now that they knew about metacognition. A couple of students raised their hands. I invited them to add their names to our chart. Of course we clapped and cheered as they etched their names into Room Two’s history books! As time progressed, others began to slowly add their names to our list. We applauded them, also!

The Transfer of Metacognitive Skills

One of positive benefits of the metacognitive strategies and activities presented to the students was the natural occurrence of the transfer of these skills into other areas. Even though we focused on metacognition as it applied to math problem solving, the approach of constantly highlighting the use of metacognition and
talking openly about it led to the discussion and use of metacognition in areas other than math.

In reading, when the students made a story prediction, they were asked how they arrived at that prediction. This necessitated an explanation of the thinking which led to their prediction. Students often noted that metacognition was being used in this process. This showed that the transfer of metacognitive skills was taking place. Metacognitive strategies were showing up in other areas as well (e.g., in science when hypotheses were being made and on the playground when solutions to confrontations were being designed) and students explained how they arrived at their decisions. It was amazing to me how easily and naturally metacognition could and was being transferred to other areas.

Some Final Thoughts

Instructors need to constantly coach students as they begin to work with metacognition. When a student responds to a question they should be encouraged to share their thinking in depth. Many probing questions should be asked to help students clarify their thinking. As the student explains his/her thought process, point out to the rest of the children that their classmate has just demonstrated metacognition. Repeated, open discussions about
metacognition and its uses will assist the children in feeling more comfortable with it.

Working together to promote self assessment and constructive assessment of others should be the goal of the thinking classroom. By structuring many opportunities for our students to become involved in their learning we are making them take an active role in their education. They are no longer passive learners waiting to be told whether or not they "know" something. We are allowing them to become engaged in the learning process enabling them to make decisions about what they know, what their strengths are, and where they need improvement. I believe that this approach is much more effective than the traditional approach to education, as students will remember the experiences and materials learned because they own them!
I believe the integration of metacognition into the elementary classroom is important if we want students to learn to be productive thinkers. The goal of the lessons presented in Chapter III is to create a classroom which nurtures good thinking in its students. The curriculum takes students who know nothing about metacognition and teaches them metacognitive techniques step-by-step. The classroom becomes a haven for metacognition, which is a word that becomes as common as to the students as "awesome"!

But does the curriculum that I've created do all that I had hoped? How effective was the curriculum in developing the three levels of metacognition as suggested by Schoenfeld? To find out, I conducted a small interview study which assessed nine fourth grade students' metacognitive abilities before and after instruction in metacognition. This chapter outlines the study format, explains the procedure used in conducting the research, discusses the interview process, and presents the results.
The structure of the research was as follows:

1. The 24 students in my fourth grade class took a written pre- and post test to assess their math problem solving abilities. The tests consisted of four simple math word problems (see Appendix B).

2. All 24 students completed the written tests on their math problem solving ability individually.

3. Of those 24 students, nine were chosen to participate in this study.

4. The California Achievement Tests were used to determine the student ability levels in mathematics. Three students were chosen to represent each of the three levels of mathematical ability; average, above average and below average.

5. Once the students were chosen to participate in this study, their former teachers were questioned to find out if they had been exposed to any formal training in metacognition. (The answer was no for all nine students.)

6. The nine students were given individual pre- and post-interviews to assess their metacognitive abilities.

7. Predetermined questions were developed to be used during the interviewing processes.

8. Both the pre- and post-interviews were tape recorded.

9. Written notes about the students' physical activity during the pre- and post-interviews were taken.

10. All 24 members of the class were taught about metacognition for a period of five weeks.
The nine students were given a post-interview at the end of the study to determine any changes that may have occurred in their metacognitive abilities.

The Procedure

All 24 members of my fourth grade class were instructed in metacognitive strategies for a period of five weeks. The interviews, however, were conducted with only the nine preselected students. Time constraints and the large number of students involved prohibited me from interviewing all of the participants.

The first step in the process was to have all of my students take a written pretest to establish the level of their math problem solving abilities. Each student took the test individually. The students were asked to solve a series of four simple math word problems (see Appendix B) which were taken from the Project Plus math word problem series (1984). After taking into consideration the written pretest results and the California Achievement Test scores, nine students were selected to take part in this study. These students represented average, above average, and below average math abilities (three from each level).

The nine students were then interviewed to determine their metacognition capabilities before the actual instruction began. At
the end of five weeks of instruction in metacognition, the students were given a post-interview to assess any changes which may have taken place because of the intervention.

The structure of the pre- and post-interviews remained the same, only the numbers used in the math word problems changed. In problem #1, the students were asked to solve a math word problem written on a sheet of paper. In the pretest it read: **Sean paid for the toy he bought with 4 coins. Which toy did he buy?** Pictured on the sheet were three toys with price tags attached. The ball cost 27¢, the car cost 37¢, the boat cost 47¢. The post test read: **Sean paid for the toy he bought with 7 coins. Which toy did he buy?** The same toys were pictured with new prices. The ball now cost 67¢, the car 87¢, and the boat 97¢. The students were told that they could use any coins but a half dollar when solving this problem. They were able to write on the paper when solving each problem. I took written notes on the physical actions of the students as they worked.

When they completed the task, the students were asked to describe how they arrived at their answer. They were directed to reflect on the procedures they used to reach their solution and verbalize these procedures step-by-step. In some interviews it was
necessary to ask the students additional questions to clarify their responses. I tape recorded their responses.

Next, the students were asked to attempt a think aloud protocol (problem #2). In the pretest interview, the question said: **How many legs on 8 cats?** Problem #2 of the post-interview was rewritten to say: **How many legs on 18 cats?** The tape recorder was running as the directions were explained and as the students completed problem #2. Again, some additional questions were asked to clarify student responses.

Finally, students were asked questions to determine what beliefs they had about their abilities as math problem solvers. These questions were:

1. Do you know what kind of problems you were doing today?
2. Do you enjoy solving math word problems? Why or why not?
3. Are you good at solving math word problems?
4. What makes someone a good/not so good math word problem solver?

The interview questions were designed to relate to the three categories of intellectual behavior suggested by Schoenfeld (1987). These categories are:
1. Your knowledge about your own thought processes.

2. Your control or self-regulation of your thought processes.

3. Your beliefs and intuitions about a topic. For example, what ideas about mathematics do you bring to your work in mathematics, and how does that shape the way you do math? (1987, p. 190)

The interview questions were formulated to try and identify the abilities of the student in each of Schoenfeld's categories. They were designed to trigger responses that, when analyzed, would indicate the student's strengths and weaknesses in each category. The questions were piloted on two students and one adult to see if they were suitable for the study. They worked very well in the pilot test so were used during the actual pre- and post test interviews.

In general, the students' descriptions of their thinking processes in problem #1 were analyzed to determine their knowledge about their thought processes (especially precision of language and accuracy of description). These same descriptions, along with the think aloud protocols for problem #2, were used to assess their self-reflection in problem solving.

The last questions in the interview (Do you know what this kind of work is called that you are doing? How do you feel about problem solving? Do you enjoy solving math problems? Are you...
good/not so good at math problem solving? What makes you
good/not so good at it?) were designed to find out what the
students' attitudes were about their problem solving abilities and
their reasons for their attitude. Did they have a positive or negative
attitude? Did they conceptualize their abilities as either fixed
(Entity) or flexible (Incremental) as suggested by Bempechat,
London, and Dweck (1991, p.12)? How did their attitude affect their
abilities? I tried to answer these questions based on the students' responses in the interview session.

**Procedures for Scoring**

The instrument that I used to score the students' pre- and post-interview transcripts was a scoring sheet designed to coincide with Schoenfeld's three categories of intellectual behavior. The students' pre- and post test scores were tallied on the same sheet. I differentiated between them by tallying them in different colored ink. By looking at the color of the ink I could tell whether the marks were for a pre- or post test and whether they were for problem #1 or problem #2.

The objectives for the first category, knowledge of one's own thought processes, were derived from the class chart which addressed the criteria for determining a good explanation of thinking (precision in language, sequential steps, complete description).
Under precision in language, I noted some elements of speech which would contribute to imprecise language. These elements were: missing words, fuzzy phrases, and the use of ambiguous pronouns. Elements which contributed to precise language were: using unit labels, explaining reasons, and using clear sentences. When I evaluated each students' pre- and post-interviews, I looked at each sentence individually. I scanned it for instances when a student used one of the subcategories of precision in language. I would make a tally mark on their score sheet under the correct heading. I then counted the total number of sentences (I refer to as phrases below), the total number of unit phrases, and the total number of words in all of the student responses for problem #1 of the pre- and post-interviews. I used these totals to arrive at a percentage of missing unit phrases relative to the total number of unit phrases, "because" phrases and fuzzy phrases relative to the total number of sentences put forth by the students, and the percentage of ambiguous pronouns used by the students relative to the total number of words spoken.

In this analysis, I only used the data from problem #1 pre- and post-interviews because those responses provided a much richer source of information when examining the thinking processes of students, than the responses from problem #2. The responses gathered from problem #2 disclosed very rigid "pattern-like" thinking by the students as the problem was fairly straightforward.
and did not require much divergent thinking. If I were conducting this study again, I would use a two-step word problem for the think-aloud portion of the interviews (problem #2). This would allow more creative solutions to emerge.

The following are examples from the student interviews which show what is meant by each subcategory of precision in language. The blank indicates a place where I thought something was missing. The parenthesis at the end of some of the examples indicates what I thought was missing.

1. **Percentage of missing unit phrases relative to the total number of complete phrases**
   * I started looking for 8_. (coins)
   * That's 5_, then add 2 pennies and you have 7_. (coins, coins)
   * So I think of 1_ and there are 8. (cat)

2. **Percentage of “because” clauses (or the equivalent) relative to the total number of phrases** (when the students were able to explain why they did or did not do something in their thinking process)
   * Then I thought the car was right because I started to use quarters instead of dimes.
   * I figured it couldn't be 67 because it would take 6 dimes, a nickel and two pennies which makes 8 coins.

3. **Percentage of fuzzy phrases relative to the total number of clear phrases** (each sentence was counted as a phrase)
   * I didn't quite get anything out of them.
   * And I thought, well, I didn't think it would be this one because of the 4 coins.
   * And I thought it was 40¢ and it still wasn't the same.
4. The ratio of ambiguous pronouns to total number of words

* Well I thought if this was 4 coins, then this had to be more coins than 4 coins because it costs more than this costs. (the car, the boat, the boat, the car)

The tabulated scores for the pre- and post-interviews will be presented separately for each of the above four subcategories: percentage of missing unit phrases relative to complete unit phrases, percentage of because phrases relative to total number of phrases, percentage of fuzzy phrases to total number of clear phrases, and percentage of ambiguous pronouns relative to total number of words.

To assess student abilities in self-regulation and self-control, I reread the child's transcript, followed his/her thought process and made notes of places where the child had forgotten to describe a step in his/her thinking process. It was evident in many cases that the child had described steps A and C in the thought process, but had forgotten B. I knew that B had to have been done because there was no way the child could have gotten from A to C without step B. I called this skipping a step in the process. The places where steps were missed in the thinking process were marked with an SK on the transcript.
Finally, student responses to the questions which coincide with Schoenfeld's third category of beliefs and intuitions were analyzed separately and the results presented question by question. In addition, the class pre- and post tests were analyzed for the number of problems done correctly.

**Changes in Math Problem Solving**

It was very exciting to see the results of the class pre-/post tests which were given at the beginning and end of the study. The test questions were the same, only the numbers had been changed. The increase in the number of students who answered either all of the problems correctly or 75% of them correctly doubled from the pre- to the post test. The results are presented in Table 1.

<table>
<thead>
<tr>
<th>Number of Problems Correct</th>
<th>Percentage of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
</tr>
<tr>
<td>4 correct</td>
<td>13%</td>
</tr>
<tr>
<td>3 correct</td>
<td>21%</td>
</tr>
<tr>
<td>2 correct</td>
<td>41%</td>
</tr>
<tr>
<td>1 correct</td>
<td>25%</td>
</tr>
</tbody>
</table>

Also, it was interesting to note how much more organized the students were in presenting their results on the post tests. In both the pre- and post tests, three of the four problems should have had
labeled answers. An example of what is meant by a labeled problem would be the answer: You now have 23 cents left. This can be contrasted to an unlabeled problem which would simply say: 23. The students labeled more of the problems in the post test than in the pretest. Table 2 shows the results.

<table>
<thead>
<tr>
<th>Number of Problems Labeled</th>
<th>Percentage of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
</tr>
<tr>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>2</td>
<td>21%</td>
</tr>
<tr>
<td>1</td>
<td>42%</td>
</tr>
<tr>
<td>0</td>
<td>33%</td>
</tr>
</tbody>
</table>

I feel that what brought about these results was the large amount of class time spent on emphasizing to students the importance of taking their time and checking their work. I believe that this encouraged the children to be more thorough in the presentation of their results, thus causing the rise in the number of labeled solutions. It would be interesting in a subsequent study to compare problem solving improvement for classes taught word problems traditionally with classes taught with a metacognitive approach, to see if students actually learn to solve word problems better with a metacognitive approach.
Changes in Metacognitive Performance

Mean length of initial response. Prior to scoring the quality of their responses, I scored the total number of unprobed words that the students used to describe their thought processes. Words like "um", "well", and "okay", as well as some repetitions, were not counted. The average length of the student response to describe their thought process in solving the two math problems increased by 54 words in the post test interviews. The mean length of the pretest responses was 126 words (the length of the pretest responses ranged from 56-196 words). The mean length of the post test responses was 180 words (the length of the post test responses ranged from 120-273 words).

Clearly, there was an increase in how much the students said in their post-interview. What accounts for this difference? There are several possible explanations. One of the major differences that I noticed when looking over the transcripts was that the students' descriptions were more complete in the post tests. They were better able to describe, with detail, their responses. There was also an increase in the number of times the students explained their actions. In the pretest, on six separate occasions, the students offered a reason why they did something. In the post test, there were 19 occasions. Were the students slowing down and taking more
time to not only think about what they did but also think about why they did it? It would seem so.

The increase in the length of the response of problem #2 in the post test may have been caused by the larger numbers used in this problem. The post test problem #2 required the students to regroup. Many students verbalized these steps in their descriptions which would partially account for the increase in the number of words used. One student describes regrouping by saying, "That would be 18x4. That is 4x8 is 32, so you carry the 3 and multiply 4x1 which is 4, plus the 3 is 7." A student who explained how the process of regrouping was carried out would definitely have a larger number of words in their overall response than a student who did not explain this process.

Next time, I would make sure that the pre- and post test problems required the student use of the same type of math processes. A better question for the post test would have been: How many legs on six cats, for example. Or I could have included a more complicated regrouping problem on the pretest. I suspect students explicitly described the regrouping process because I had modeled this in class. It would be interesting to see if in fact students would spontaneously discuss regrouping on a pretest.
Another interesting difference is the increase in the number of students who mention the problem constraints when describing their thinking in problem #1 of the post test. They were told that they could not use half dollars to solve the problem. Many of the students mentioned this as they metacogitated. One student tells us, “I started with quarters, well, you said we couldn’t use half dollars.” Was it the problem constraints which caused students to think more and therefore add to the total number of words in their response? Or was it that they were able to more fully describe their thought processes in the post test interview, which included reviewing the constraints of the problem, causing an increase in the number of words? It is hard to know for sure.

However, there was some evidence that students were generally becoming more aware of problem constraints. Both the pre- and post test problem #1 had a constraint concerning the number of coins. More children mentioned this constraint on the post test than pretest (see later self-regulation analyses).

**Precision of language.** I used four subcategories to determine the precision of the students' language. The results for each subcategory are presented in Tables 3-6.

1. **The Number and Percentage of Incomplete and Complete Unit Phrases** was the first subcategory.
Table 3

<table>
<thead>
<tr>
<th>Kind of Unit Phrase</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incomplete Unit Phrases</td>
<td>34 (35%)</td>
<td>41 (30%)</td>
</tr>
<tr>
<td>Complete Unit Phrases</td>
<td>63 (65%)</td>
<td>94 (70%)</td>
</tr>
<tr>
<td>Total Phrases</td>
<td>97</td>
<td>135</td>
</tr>
</tbody>
</table>

The percentage of phrases containing missing units did not change much from the pre- to post-interview sessions. Essentially, the results were the same. When looking at the individual scores I noted that some students did better on the post test and some did not.

While there was no major shift one way or another in the pre- and post-interviews, there was some evidence of an increase in the proportion of labeled phrases on the whole class post test (see Table 2, use of unit labels). This may be because in think aloud protocols there will always be some measure of incompleteness, whereas students learned the importance of units in presenting a formal written answer.

2. The Number and Percentage of “Because” Phrases Relative to the Total Phrases was the second subcategory. Again, the score for this category was derived from the pre- and post-interviews of problem #1 only. The results are shown below.
Table 4
The Number and Percentage of "Because" Phrases Relative to the Total Phrases

<table>
<thead>
<tr>
<th>Kind of Phrase</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because Phrase</td>
<td>6 (9%)</td>
<td>19 (22%)</td>
</tr>
<tr>
<td>Other Phrase</td>
<td>59 (91%)</td>
<td>67 (78%)</td>
</tr>
<tr>
<td>Total Phrases</td>
<td>65</td>
<td>86</td>
</tr>
</tbody>
</table>

The number of instances when the students told the "why" of their thought process showed some suggestion of improvement in the post-interviews. Students seemed to be more aware of the reasons why they did certain things when trying to solve the problem and were better able to verbalize these thoughts. An example of a child's response in this category would be when one student explains, "I figured it couldn't be 67 because it would take 6 dimes, a nickel, and 2 pennies which makes 8 coins." In his response, this student did not stop after saying that it could not be 67. He continued on and told us how he came up with that conclusion.

3. The Number and Percentage of Fuzzy and Clear Phrases in problem #1 was the third subcategory. The results may be seen in Table 5.
Table 5
The Number and Percentage of Fuzzy and Clear Phrases

<table>
<thead>
<tr>
<th>Kind of Phrase</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuzzy Phrase</td>
<td>12 (18%)</td>
<td>12 (14%)</td>
</tr>
<tr>
<td>Clear Phrase</td>
<td>53 (82%)</td>
<td>74 (86%)</td>
</tr>
<tr>
<td>Total Phrases</td>
<td>65</td>
<td>86</td>
</tr>
</tbody>
</table>

The number of unclear phrases remained the same, but there was a small increase in the number of clear statements. However, overall, there was not a dramatic shift in the proportion of fuzzy phrases.

4. The Number and Percentage of Ambiguous Pronouns Relative to Total Words for problem #1 (pre- and post test) was the final subcategory of Precision in Language.

Table 6
The Number and Percentage of Ambiguous Pronouns Relative to the Total Words

<table>
<thead>
<tr>
<th>Kind of Word</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambiguous Pronoun</td>
<td>23 (3%)</td>
<td>22 (2%)</td>
</tr>
<tr>
<td>Total Words</td>
<td>779</td>
<td>1096</td>
</tr>
</tbody>
</table>

Again the number of ambiguous pronouns remained the same, although the total number of words increased. Overall, however, there was not a clear improvement in the results of the ambiguous
pronoun survey from the pre- to post-interviews. Some individuals did better, some did worse, and some showed little change.

Thus, apart from the increased instances of students giving reasons for their actions (because clauses), there was no dramatic improvement shown in any of the other measures done to assess students' precision in language.

**Self-control and self regulation.** After scoring the transcripts for the students' precision in language, I moved on to the next category which was **Self-Regulation and Self-Control**. When scoring this category, I determined the number of steps that each problem should take to complete. In my analysis, problem #1 took four steps. They were: reads the question, notes important information and data, refers to question to check status of their work, and answers problem with reference to the question. Problem #2 (Think Aloud problem) took only three steps. The problem was quite short and the third step (refers to question to check status of their work) was not necessary to complete the problem. The number of steps in problem #1 and #2 were the same in the pre- and post test problems.

Next, I looked at the students' pre- and post-interviews (separately) to see how accurate they were in reporting the use of each of these steps. I read each child's interview and gave them a
check for each step that they had commented on in their thinking protocol. If they missed a step, they received a zero for that step.

The results for each step in the process are presented below the key

(P1= pretest problem #1; P2= pretest problem #2; PT1= post test problem #1; PT2= post test problem #2; na= not applicable; + = utilized the step; - = partially utilized the step; 0 = did not utilize the step).

Table 7
Number of Children Reporting a Given Step in Problem Solving

<table>
<thead>
<tr>
<th></th>
<th>Reads the Question</th>
<th>Notes Key Information</th>
<th>Evaluates Answer With Respect to Key Information</th>
<th>Answers With Reference to Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1 P2 PT1 PT2</td>
<td>P1 P2 PT1 PT2</td>
<td>P1 (na) PT1 (na)</td>
<td>P1 P2 PT1 PT2</td>
</tr>
<tr>
<td>+ 5</td>
<td>8 6 8</td>
<td>1 5 8 6</td>
<td>5 7</td>
<td>3 3 6 6</td>
</tr>
<tr>
<td>- 0</td>
<td>0 0 0</td>
<td>1 2 0 2</td>
<td>1 0</td>
<td>0 4 0 2</td>
</tr>
<tr>
<td>0 4</td>
<td>1 3 1</td>
<td>7 2 1 1</td>
<td>3 2</td>
<td>6 2 3 1</td>
</tr>
</tbody>
</table>

Table 8 is a summary of the plus category in Table 7, which indicates the number of students who used a given problem solving step.

Table 8
Mean Number of Children Reporting a Given Step in Problem Solving

<table>
<thead>
<tr>
<th>Step</th>
<th>Pretest</th>
<th>Post Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reads Problem</td>
<td>6.5</td>
<td>7</td>
</tr>
<tr>
<td>Notes Key Info.</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Evaluates/Key Info.</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Answers/Question</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
All of the categories show an increase in the number of students utilizing that step, some categories show more of an increase than others. Category 2, noting key information, more than doubled. This is probably because we emphasized describing your thinking process step by step, stating exactly what you did and thought as you went along. We spent a lot of class time focusing on this aspect of metacognition. We practiced it frequently. In the pretest, I am sure there were many students who did note key information in the problem but failed to mention it. In the post test, I feel that the students were more aware of their thinking and concentrated on describing each step of it clearly. That is why we see a rise in the number of students telling us that they noted key information in the problem.

The following are excerpts from a student transcript which illustrate the attention paid to key information and problem constraints in the post-interview.

Pre-Interview: Well I started with 27 cents worth. I know a quarter equals 25 cents and...

Post-Interview: Sure. First, I read the problem. I thought about what I had to find out which was what toy did Sean buy with 7 coins. You told me I couldn't use a half dollar so I thought I'd have to use a lot of quarters.

The increase in the number of students answering with reference to the question (step four) could have been caused by a
few things. First, it may have been that the students were utilizing their training in labeling objects. If this was the case, then for problem #1 of the post test, students were not likely to say that their answer was simply, “The boat.” But instead might say, as one student did, “So it had to be the boat. When I tried it, it came out to 3 quarters, 2 dimes, and 2 pennies which is 7 coins or 97¢.” This student supplied a much more complete answer which referred to the question: Which toy did Sean buy with 7 coins?

Another possibility for the increase in this category is that the students, as with category 2, were more aware of their thought processes and better able to articulate them in the post-interview. In the pre-interview, students may have referred to the question as they came up with their final answer, but may not have mentioned that step when describing their thinking.

Alternatively, the students’ training in metacognitive skills may have encouraged them to add the step of checking to their repertoire of problem solving strategies. It seems possible. We talked about checking our answers with reference to the question (to make sure it made sense) and practiced this quite often. It could be that in the pretest the students were lacking this step of the process and simply found a solution and felt they were done (without bothering to check it with the question). Students were already good
at noting the importance of reading the problem, at the time of the pretest.

Beliefs and intuitions. Finally, to assess the students' beliefs and intuitions, I reviewed the student responses to each of the four questions which were asked in the pre- and post-interviews. The results from each question are presented in the Tables below.

Table 9 shows the results of question one which asked: Do you know what kind of problems you were doing today?

<table>
<thead>
<tr>
<th>Response</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>no</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

The big difference in the post test results is probably because we spent so much time talking about math word problems (and called them just that) in our metacognitive lessons. I also told the students the correct answer when administering the pre-interview. So either or both of these events could have caused the increase in this category.
Table 10 represents the students' responses to question two which inquired: Do you enjoy solving math word problems?

<table>
<thead>
<tr>
<th>Response</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (usually, most of the time)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>No (don't know, kinda, sometimes)</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

There was no change in the level of student enjoyment of problem solving. I was surprised at this. I assumed that because of our work with metacognition and problem solving the students would feel comfortable with solving problems and therefore enjoy them more. Actually, students started out with a fairly high level of enjoyment.

Table 11 shows how the students answered question three: Are you good at solving math word problems?

<table>
<thead>
<tr>
<th>Response</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (pretty good, guess so)</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>1/2 (a little, sometimes)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>No (not so good)</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Although the majority of students indicated that they enjoyed solving word problems on the pre-interview, only a minority thought they were good at solving them. Their perception of their ability changed from the pre-interview to the post-interview: now the majority think they are good at solving word problems, and there is greater congruence in their judgments of liking and ability. Interestingly, there were some children at all ability levels who thought they were not good at solving word problems at the time of the pre-interview and the curriculum was successful in changing their conceptions about their abilities across ability levels. However, there were two children who initially said they didn’t enjoy and were not good at solving math word problems who still maintained that opinion at the time of the post-interview.

Question four asked the students to share their ideas about what makes someone good or not so good at solving math word problems. Their responses were divided, according to meaning, into four categories: abilities, practice-studying-knowledge, motives/attitudes, and reflection (either specific or general). The actual student answers are listed in parenthesis under the category name. The results were presented according to the types of responses given, not the total number of responses. So in one category (specific ideas about reflection) you see a 10 meaning that
10 answers were given that fit into this category. I was looking at the content of the responses given in this category, not the quantity.

Finally, I looked at the students' responses to determine the total number of students expressing metacognitive ideas as they answered question four. The results, which are shown in Table 13, are presented under three categories: general metacognitive ideas, specific metacognitive ideas, and no metacognitive ideas. Table 12 shows the student responses to question four which asked: What makes someone a good/bad problem solver?

Table 12
Student Opinions on What Makes Someone a Good or Bad Problem Solver

<table>
<thead>
<tr>
<th>Categories of Student Responses</th>
<th>Pre-Interview</th>
<th>Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abilities</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>(smart, clever, able to solve hard ones, gets answer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practice, Studying, Knowledge</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(studies math, knows what to do)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motives or Attitudes</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>(likes p. solving, tries best, does not like it or try)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflection</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>* general</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(thinks: a lot, hard, about it)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* specific</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>(takes time, checks work, reads carefully, writes things down, does it step-by-step, uses metacognition)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 13
Number of Students Expressing Metacognitive Ideas in Response to Question Four

<table>
<thead>
<tr>
<th>Kind of Idea</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Interview</td>
</tr>
<tr>
<td>No Metacognition</td>
<td>3</td>
</tr>
<tr>
<td>General Metacognition</td>
<td>1</td>
</tr>
<tr>
<td>Specific Metacognition</td>
<td>5</td>
</tr>
</tbody>
</table>

Again, I was surprised at the results. There was not much change in any of the categories from the pre-interviews to the post-interviews. I was also amazed that the students already had some ideas about metacognition before I began my study (see Reflection category of pretest, Table 12). This could be the result of former teachers instructing them in problem solving techniques. I know that most of our staff teaches the Five-Step method of problem solving (Read, Find, Design, Solve, and Check) from Holt Mathematics. Learning this method could have caused the students to respond as they did on the pre- and post-interviews.

Another surprise I encountered was that the findings on Question Four were at variance with what I observed in the class as a whole. When the students were asked what made someone a great thinker at the beginning of the study their responses were smart, famous, etc. When the study was completed their ideas changed quite a bit to include thinking carefully, going step-by-step, taking
their time, etc. These are very similar to the responses given to question four on both the pre- and post-interviews. Why were the pretest responses so dissimilar? I did not get many responses like smart, famous, etc. on the question four pre-interview because at that time the students did not equate problem solving with thinking. I believe they felt that a great thinker just is, whereas a problem solver has to do. Students thinking along these lines would be more likely to share responses having to do with a person's actions (like writes things down, takes his/her time, checks, etc.) which is the case with many of the question four pretest responses.

Overall, I felt that my questioning of the students in categories one to four was not extensive enough to get as much information about students' beliefs and intuitions as I had hoped. I did not probe the students' thinking enough and therefore the answers received were somewhat superficial. I just did not have much to work with in the way of in depth responses. I would encourage anyone trying this study again to spend some additional time doing pilot interviews, which deal with the students' beliefs and intuitions, in hopes of creating a question format that would achieve richer results.
Improvement in Problem Solving and Metacognition

In the previous sections, I have shown that there was improvement in student word problem solving abilities, as well as in student abilities to engage in metacognitive reflection, that came about as a result of my curriculum. An unresolved question then remains: To what extent are the two improvements related to one another?

As a preliminary step in answering this question, I decided to use the Spearman rank order correlation to look at the relationship between changes in student problem solving abilities and changes in their metacognitive abilities. I began by determining overall change scores for each student as they related to their problem solving abilities, number of words produced, and positive metacognitive strategies used. I assigned each student a rank order in each category (from highest to lowest) according to their change scores. I measured the correlations between the student rank orders in problem solving abilities and number of words produced, problem solving abilities and positive metacognitive strategies used, and number of words produced and the number of positive metacognitive strategies used. The results, which are presented below, are encouraging.
The first correlation that I made was between the rank order of students' problem solving abilities and the rank order of the number of words produced. The correlation was .58, a score which approaches significance (an r of .60 would be significant at the .05 level, one-tailed). I feel this is an impressive result considering the small sample size of nine students.

The next correlation that I made was between overall rank order of student problem solving abilities and the number of positive metacognitive strategies used. I included in the metacognitive strategies the because phrases, self-regulation, and answering with reference to problem constraints. When my calculations were done, I again came up with a substantial positive correlation score of .48.

Finally, for interest, I decided to test how related the two metacognitive measures were. So I looked at the correlation between the rank orders of students according to the number of words produced and the number of positive metacognitive strategies used. When calculated, the correlation was .57.

It should be noted that I was correlating change scores, not scores that indicated absolute levels of performance. The amount of change between the pre- and post tests were not directly related to student ability levels. Some of the lower ability students showed a lot of change and some showed little change, as was the same case
with the higher ability level students. Further, it is interesting that what is reflected in these results are the scores of tests taken at two quite different time periods. This would indicate that there is a real relationship between the scores (not just that the student was having a good or bad day).

The message that these correlation scores send out is one of encouragement that there is some relationship between the infusion of metacognitive strategies in the classroom and improvement of student problem solving abilities. A message which also suggests that further exploration is necessary on this subject, possibly in the form of a future study. I will address this in more detail in Chapter V making suggestions for how to structure a future study.
CHAPTER V
CONCLUSIONS

Main Findings

The goal of this thesis has been to explore what a metacognitive curriculum would look like in the elementary classroom and to begin to assess how students respond to such a curriculum. One of the goals of teaching students about critical and creative thinking is to have them learn to value their thinking processes and the thinking processes of others as well as to gain greater skill in using the processes. Metacognition is an important component of critical and creative thinking, mainly, because it teaches our students how to effectively monitor their thoughts to promote intellectual growth. By being aware of their thinking processes, students should not be stymied when an answer does not occur to them automatically. Rather they have explicit strategies they can call upon to help them when this happens.

After a careful review of much of the literature on metacognition, it seemed to me that metacognition could easily be infused into an elementary school curriculum to the benefit of all involved. So with this in mind, I decided to develop activities and lessons which would support the acquisition of metacognitive skills in students. But what would be the underlying structure of these
lessons? I concluded that the ideas put forth by Robert Swartz (1987) and Alan Schoenfeld (1987) would best suit the instructional needs of the classroom teacher and the curriculum. The clarity of their methods and the ease with which they could be utilized were two factors that led to their selection.

The ideas Robert Swartz (1987) presents would best assist the classroom teacher when integrating metacognition into the curriculum. Swartz suggested three major practices that teachers should emphasize in their thinking skills' instruction. They are: classify the thinking (by using the correct terms), describe or analyze the thinking processes, and recommend or prescribe ways of thinking. I felt that these three practices could be easily implemented in the classroom, for both the teacher and the students. So the instructional suggestions which Swartz made can be seen woven throughout the lessons presented in Chapter III.

What about metacognition itself? I needed to find a way to focus on metacognition in more concrete terms. Thinking about thinking was too broad if I were going to try to assess students' growth in abilities. Schoenfeld's thoughts on metacognition were just the organizing components I needed for assessing the development of metacognitive skills in my students. He divided metacognition into three separate categories of thinking: knowledge
of one’s own thought processes, self-control and self-regulation, and beliefs and intuitions. I would measure the students’ growth in metacognitive abilities according to these three areas.

The first conclusion, which I drew from classroom observations and student interviews, was that students of all ability levels could describe their thinking. By doing this they demonstrated to me that they possessed some metacognitive abilities to begin with. Evidence supporting this conclusion is presented below in the form of student transcripts taken from the pre-interview session, problem #1 (Which toy did Sean buy with four coins?). A sample from each ability level is given.

S1 (above average): If you think of all the combinations for the ball, like 25 cents and two more pennies to go to 27 cents, that’s only three. And then if you had two dimes and a nickel and two pennies, that would be five coins. So you couldn’t have only four. So it wouldn’t be four. If you have like the nickels, four nickels would be 20 cents. That would already be four coins. And any other combinations would be four coins. Then the little toy car could be 25, plus 10 cents, plus two pennies would be 37 cents and four coins. So that would be the right answer. And the toy boat you couldn’t do that either. 25 plus 10 would be 35, plus another ten would be 45, plus the two cents would be 47, but that would already be five. And the other combinations wouldn’t make it. Well, they wouldn’t add up to four coins.

S2 (average): First I read the problem. Then I looked at the boat and I said the two highest ones, the two quarters equals twenty-five. And then... I mean fifty so
that's over forty-seven cents. So that it couldn't be two quarters. So then the dimes and it says he only used four coins and four dimes equals forty cents and then the seven cents. Then I looked at the ball. Then I said twenty-five cents would be a quarter, then twenty-six, twenty-seven, twenty eight. So then I decided two dimes and then something... a nickel and it would have to be two pennies. So then I looked at the car. I thought twenty-five plus ten equals thirty-five. So thirty-five, then a nickel, then that's three, then two pennies equals thirty-seven.

S3 (below average): Well, first I read it. Then I was thinking of two ten cents', five cents, and two pennies. So I didn't know, I thought it was only four because I didn't count on my fingers. Then I gave the problem and it wasn't four coins it was five coins and I did the same mistake. I did the same thing the second time I did it. For 37 cents, I mean 47 cents I put a quarter, a dime, another dime, and two cents. And I thought it was 40 cents and it still wasn't the same. So I figured it out the other way using a quarter, ten cents, and two pennies and it equals four cents, I mean four coins.

While the student interviews demonstrated that they were capable of metacogitating, it was also evident from their interviews, and my classroom observations, that their skills were in need of finetuning. I concluded that the areas to focus on would be precision in language (ambiguous pronouns, unit labels, and giving reasons for actions taken), understanding self-regulation and self-control (identifying problem constraints), formulating answers clearly, and reasoning skills.
After carefully analyzing the pre- and post-interviews, I was able to conclude that there was evidence of student growth in a number of aspects of metacognition after the curriculum intervention. The clearest improvement was shown in the confidence and ease with which students conducted themselves in the post-interviews. The large increase in the number of words produced supports this notion. The students also increased their skill of supporting their actions with reasons, noted in the larger number of “because” clauses in the post interviews. I also noticed that students’ answers were formulated more clearly as evidenced by their referral to the initial question when finalizing their solutions. Many students were easily able to identify the constraints of the problem and used this information constructively when developing their plan of action for solving the word problem. Finally, the post-interview results revealed that there was an increase in the number of students who felt that they were good math problem solvers. When asked in the pre-interview if he were a good problem solver, one student responded, “I don’t know.” In the post-interview that same student said, “Yes, I’m pretty good!”

There was evidence which supported an increase in the areas mentioned above, but what about the areas in which the evidence was less clear in particular, precision in language and enjoyment of problem solving? Why was there not an increase shown in those
places? The first major factor which I feel influenced the amount of growth students exhibited was the duration of the metacognitive instruction. It spanned a period of five weeks. This time frame was chosen to be able to complete the study, analyze the results, and complete my thesis in a reasonable amount of time. Looking back, I think the amount of time was too short to expect conclusive results in all areas. Acquiring metacognitive skills and having them become automatic takes time, more than five weeks! I would suggest that another study be conducted over a period of a year. The pretests should be done in September, metacognitive instruction should be taught throughout the school year, and the post tests should be given in June. The possibility of growth in metacognitive skills that might occur over that period of time is exciting!

I am confident that the results of the study would have been more conclusive if I had expanded the length of time between the pre- and post-interviews. I was able to notice some changes occurring in my students, as I continued to focus on metacognition up until the end of the year (after the five week study had been concluded). There certainly was no way that I was going to stop the gains that I felt the students had made up to that point, nor would the students have wanted to stop! While no formal assessment was done, I continued to find evidence of improvement occurring in my students. For example, they were having conversations about
problem solving strategies, comparing the pros and cons of each. They were giving certain procedures frequently used pet names (like the Joey Method, or the Count and Multiply Method). They were loving the challenges that thinking about thinking had brought them. I feel that the evidence gained from observing the students’ behaviors (for the remainder of the school year) supports my conclusion that the study should be conducted for a longer time period.

Another factor which I feel could have affected the outcomes of the post-interviews was the automaticity of some of the mathematical processes utilized when solving the word problems, especially problem #2 of the post-interview. Problem #2 required the students to multiply by regrouping. For the students who truly understand the processes involved in regrouping, I feel that the step of "carrying the three," for example, becomes automatic and they are less apt to verbalize this step. If this is the case, then the post-interview scores would certainly have been affected. In the future, it might be more valid to think of precision in language in terms of the precision with which students articulate the steps in their thinking, think ahead, and formulate their answers, rather than simply looking for unit labels and clear phrases.
Unresolved Questions

An important, unresolved question which has arisen from my work: Is there more improvement in students' problem solving skills gained from the metacognitive approach to teaching problem solving than the traditional approach to teaching problem solving? My study showed that students gained both in problem solving abilities and in metacognitive abilities. But did their metacognitive gains actually enhance their ability to problem solve?

As a teacher who has taught math problem solving skills to my students in both ways, I can attest to the differences in the “feel” of the two approaches. First of all, the five steps that I used in problem solving (read the problem, find the key information, design a plan, solve the problem, and check your answer...does it make sense?) would remain the same no matter which method I taught. One major difference, that the metacognitive curriculum stresses, is that you must constantly ask your students questions to probe their thought processes (Why do you think your answer is right? Where did you find the key information? How did you know that you were supposed to multiply? What is your plan of action?!) By always asking questions, my students had to continually reflect on their thinking processes which strengthened their metacognitive abilities. In a simple problem solving curriculum my students would
look for the right answer, find it, and then we would be done, end of discussion. In a metacognitive curriculum, my students search for the answer, discuss the pros and cons of two methods, ask questions, and compare thinking processes. When the answer was discovered, we would begin our search for the number of different ways that the problem could be solved. Students would have to use their metacognitive skills constantly! A curriculum rich with metacognitive activities is rich with learning opportunities for the children.

I see the values of problem solving being taught with the inclusion of metacognitive skills, but I must ask: Was it the metacognitive instruction or problem solving instruction which increased my students' scores on the class post tests? One way of answering this question is to review the correlation findings presented in Chapter IV. The correlation scores (.58 and .48) suggest to us that possibly there was some connection between the instruction of metacognitive strategies and the improvement of problem solving skills. But this cannot truly be determined until a further study is attempted.

How might this study be organized? First of all, it should be done with two classes. One class would be instructed purely in problem solving strategies and the other would be provided with
instruction in both problem solving and metacognitive strategies. A future study should include, in addition to the student interview portion of assessment, measures for Costa's (1985c) 10 indicators for student intellectual growth. One question is whether there is more improvement in math problem solving when there has been attention to metacognitive issues. Another question is whether the metacognitive curriculum produces more change in other more general indicators of cognitive growth than the standard problem solving curriculum. Costa provides us with this list of indicators which I will relate to behaviors that I observed in my students in the present study and would like to examine in the proposed study.

They include:

1. **Perseverance.** I saw many instances of students continuing to revise and refine their responses to be able to clearly describe their thinking. Perseverance was frequently being used at the learning center as students recorded and played back their thoughts several times until they perceived them as precise.

   In the future study, I propose it would be interesting to measure student perseverance on difficult or challenging problems. Perhaps a difficult problem could be included on the post-interview and observations could be made of how students' responded to this problem. I would predict that students with the metacognitive approach would show more perseverance.

2. **Decreased impulsiveness.** During their instruction, students were constantly being reminded to take their time, stop and think, don't rush into it, make a plan, check your work, etc. I saw the effects of these words as the students' descriptions of thinking became clearer and more concise. This indicated to me that they were not just jumping into the problem, but were taking their time and thinking about it first which resulted in better thinking.
In a formal study, the amount of time that students took to solve problems could be monitored. I would predict students with the metacognitive approach would take more time to solve problems.

3. **Flexible thinking.** Most students were very willing to adopt someone else's method of reaching the solution and were continually looking for several ways to solve the same problem. They were often heard discussing the merits of one method over another. In the future study, students could be asked to come up with as many ways as possible to solve one problem. I would predict that students exposed to the metacognitive curriculum would be able to generate more approaches to solving a single problem with ease than students in the problem solving curriculum.

4. **Metacognition.** The students went from not explicitly talking about metacognition to talking about their thinking frequently. It easily became a part of their lives. In the future study, the students' spontaneous references to strategies in talk with one another could be measured. I predict that students in the metacognitive class will easily be more able to articulate the strategies they used than students in the problem solving curriculum.

5. **Careful review.** "Take your time and check your work," was something that I was constantly stressing in my classroom. We also discussed the importance of checking and the consequences they may encounter by not checking. I saw improvement in this area in a great many of my students. In the future study, the frequency of spontaneous checking should be measured. Students in the metacognitive class should show more indications of checking their work frequently (not only when finished, but also during the process of solving the problem), than students in the problem solving curriculum.

6. **Problem posing.** It was not uncommon to hear students testing one another's metacognitive skills by saying, "All right, how would
you solve this one?” They loved to challenge each other with problems, hoping to come up with a unique solution they could label and call their own.

In the future study, measures of students’ spontaneous problem posing should be kept. Students engaged in metacognitive instruction should be able to create problems more freely than students in the problem solving curriculum.

7. **Use of past knowledge and experiences.** This indicator of intellectual growth was evident when students would refer to previously used strategies and techniques to solve current problems.

   In the future study, students should be asked to explain where their solution strategies came from. Records should be kept of the number of references made to former problems and other students’ strategies. I predict that students in the metacognitive classroom will make more references to past knowledge and experiences than students in the problem solving curriculum.

8. **Transference beyond the learning situation.** A lot of thinking skills were seen being used out on the playground at recess time. There were constantly arguments and rumbles going on which needed to be resolved. We had discussed how our metacognitive and problem solving skills would be beneficial to use when a disagreement occurred. I would hear students asking each other, “Well why did you do A? Couldn’t you have done B instead? Next time try C.” It was exciting to see our work in the class being transferred to situations outside of the classroom.

   In the future study, students should be monitored for utilization of metacognitive and problem solving strategies in areas other than math problem solving. I predict that metacognitive and problem solving strategies will be utilized by the students in the metacognitive classroom, in all areas of the curriculum. In contrast, there would be limited transfer for the students in the problem solving curriculum.

9. **Precise language.** I noticed improvement in the students’ responses, though my study did not conclude the same. We spent
much of the time talking about being exact in our speech, and I felt the students were responding to those discussions. I was surprised at the fewer number of "you knows" and "like ums" that I heard in the students' vocabulary because of our focus on precise language.

The future study should assess students' abilities to articulate the steps in their thinking, think ahead, and clearly formulate their answers as a measure for the precision of their language. I predict that the precision with which students of the metacognitive classroom verbalize their thinking processes in math problem solving will be noticeably better than that of students in the problem solving curriculum.

10. Enjoyment of problem solving. Problem solving became fun for the majority of my students. They were constantly finding solutions, sharing their thought processes, and searching for alternative ways to complete a problem. They seemed to love the challenge. Problem solving became more to them than just reading a problem and putting down an answer!

The future study should include a list of questions designed to determine the students' enjoyment of problem solving. The questions should somehow focus on the indicators of student enjoyment of problem solving that I noticed in my class: finding solutions, sharing thought processes, searching for alternative ways to complete a problem, loving the challenge! I predict that there will be greater student enjoyment of problem solving in the metacognitive classroom than in the problem solving curriculum!

These qualitative changes in my students' behaviors, informally observed by me, indicate important intellectual growth. However, these changes were not formally documented and the evidence remains in my memory of my fourth grade students and our year together. Therefore, I feel it would be imperative that a future study include ways to assess students' growth in the 10 areas which Costa has outlined for us. In this way, it could be determined if a
metacognitive curriculum produces more growth in these areas than the traditional problem solving approach.

**Parting Comment**

The experience of developing a metacognitive curriculum has led me to be highly enthusiastic about incorporating metacognition in the classroom. I believe that metacognition in the classroom promotes intelligent behaviors in students and that students utilizing metacognitive strategies are better able to understand their learning processes which will ultimately enable them to become independent learners. Students proficient in their knowledge and understanding of metacognition will not need the teacher to ask them: How did you get that? Why did you do that? What if you tried this strategy? They will be able to inquire of themselves those very same questions. As an educator, I agree with Arthur Costa (1983) when he says:

> As educators, we have the great responsibility of instilling intelligent behaviors in our students. We must teach them to value intelligent and rational action. To do so, we must provide conditions conducive to the practice and demonstration of intelligent behavior. We must believe that all students can continue to grow in their ability to behave more intelligently, and we must have faith in the ability of all humans to become increasingly more gifted. Finally, we must set an example by modeling these intelligent behaviors ourselves. (1983, p. 219)
I support Costa's notion of the importance of stressing intelligent behavior in students and tried to do so by integrating metacognition into my teaching. I hope other educators will do the same. If my thesis sparks one educator's interest in finding out more about metacognition and its value in the classroom, then I will feel that I have made a contribution to education.
BIBLIOGRAPHY


CLEAR OR UNCLEAR EXPLANATION OF THINKING

NAME:

Clear or Unclear Explanation of Thinking?

* * Circle the correct answer.

PROBLEM #1: Jay has 5 shearing bins at his sheep ranch. He splits up his 35 sheep equally among the bins. How many sheep are in each bin?

EXPLANATION: Well, I drew a picture of the sheep here. Then I put each of them where they belonged and I came up with the answer for each bin.

Is this a CLEAR or an UNCLEAR explanation of thinking?

PROBLEM #2: There are 78 students in art classes at our school. 29 of these students need paint. About how many students already have paint?

EXPLANATION: First of all, I looked for any key words that might help me solve the problem. I spotted the words “about how many” and knew that those words meant that I should estimate to find my answer. So I wrote 78 on my paper and rounded it up to 80. Then I wrote 29 on my paper and rounded it up to 30. I reread the problem to see what I should do next. I realized that I needed to subtract 30 from 80 because the problem wanted to know how many students already had paints. When I subtracted I began in the ones column and 0-0=0. Then I subtracted the tens column by saying 8-3=5. I knew my answer was 50. I went back to the problem and read it again to make sure my answer made sense. Then I labelled my answer... 50 students already had paints.

Is this a CLEAR or an UNCLEAR explanation of thinking?
APPENDIX B
CLASS WORD PROBLEMS PRE AND POST TESTS

Pretest

There were 15 people on the train. At the next stop 8 passengers got on and 9 got off. How many were on the train then?

Study the clues. Find the prices.

- and cost $1.10
- and cost $1.40
- and cost $.95

I had 48 cents. I lost a quarter. How much money do I have now?

Post Test

There were 45 people on the train. At the next stop, 18 passengers got on and 12 got off. How many were on the train then?

Study the clues. Find the prices.

- and cost $1.30
- and cost $1.90
- and cost $.85

I had 68 cents. I lost a quarter. How much money do I have now?

On her first try Lisa jumped 5 inches farther than ___________.
On her second try Paul jumped 2 inches farther than ___________.

On her first try Lisa jumped 18 inches farther than ___________.
On his second try Paul jumped 2 inches farther than ___________.

Name | Standing Long Jump
-----|-----------------------
Tony  | 5'10" 4'10" 4'5"
Lisa  | 5'4" 5'4" 5'5"
Ann   | 4'7" 4'7" 4'7"
Poul  | 4'7" 5'0" 4'7"
## APPENDIX C
### SAMPLE STUDENT RESPONSE SHEET

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>AREAS TO IMPROVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your explanation was easy</td>
<td>Try not to use as many pronouns.</td>
</tr>
<tr>
<td>to understand.</td>
<td></td>
</tr>
</tbody>
</table>

### IDEAS FOR IMPROVEMENT: Don’t let yourself use the word it in your explanation next time. See if that helps you remember to use the right words in your description.
APPENDIX D
INDIVIDUAL IMPROVEMENT PLANS

NAME: ____________________________________________

INDIVIDUAL IMPROVEMENT PLAN

STRENGTHS: I will be clear in my explanations.

IMPROVEMENTS: I will not say it in my explanations.

(created individually)

-------------------------------------------------------------------------------

NAME: ____________________________________________

INDIVIDUAL IMPROVEMENT PLAN

STRENGTHS: I will continue to take my time and list the steps in my thinking
process clearly and completely so they'll be understood by others.

IMPROVEMENTS: I will try to use nouns instead of pronouns in my
explanations of thinking. I will go to the Metacognition Learning Center and
practice describing my thinking without using pronouns (on the tape recorder).
JA will work with me at the learning center.

(created cooperatively)