THE ROLE OF STRATEGY, EFFORT, AND UNKNOWN ATTRIBUTIONS IN A METACOGNITIVE MODEL OF MATHEMATICAL PROBLEM SOLVING

by

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Previous research has documented the importance of metacognition and attributions for performance on memory and visual discrimination tasks, and in reading. The purpose of the present study was to extend this research into the domain of mathematical problem solving. Distinct causal factors, such as the role of strategies, were examined in relation to the types of metacognitive activities that occurred during mathematical problem solving. Thirty ninth-grade students who attributed performance to strategy, effort, or unknown causes on the Attribution Questionnaire for Mathematical Problem Solving were videotaped and asked to verbalize their thoughts as they solved a nonroutine mathematical word problem. Based on an analysis of the videotapes, student protocols were scored for: problem-solving progress; total metacognition; and the metacognitive activities of understanding, analyzing, exploring, planning/implementing, and verifying.

Although there were no differences in overall metacognitive involvement between the three attribution groups, there were differences in the key metacognitive

component of exploration. Students who attributed performance to strategy were much more likely to regulate their exploration than those who ascribed to effort or unknown causes, and they were more likely to solve the problem than students from the effort group. Furthermore, students who made dual attributions to strategy and effort were not as likely to regulate their exploration or solve the problem as students who made "pure" strategy attributions.

The results of the study indicate that total metacognitive scores are not as informative as specific metacognitive strategies, depending on the type of mathematical problem used. Successful problem solvers did not necessarily analyze the problem, devise a plan, or verify their solutions. They did have a sound cognitive understanding of the problem and regulated their problem-solving attempts. The results suggest the need: 1) to examine metacognitive activities in relation to the type of problem used; 2) to investigate students' perceptions of "effort" as causal to performance; 3) to investigate the effects of attributional training designed to raise students' awareness of the causal role of strategies; and 4) to examine the effects of combined strategy-effort feedback.

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To all of my wonderful friends who reminded me to exhale!

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Chapter I

Introduction

> Aside from this he (Levin) had an obscure feeling that what he called his convictions was not only ignorance, but represented an order of ideas that made it impossible to acquire the knowledge he needed (Tolstoy, 1876, p. 835).

Levin realized that the beliefs he held made it difficult for him to learn what he needed to know. There was a conscious discrepancy between Levins's convictions and his desire for a richer life. Levin's awareness places him on a forked path and his choosing the course of "knowing" may only be possible if he believes he has personal control over life events. The problem's solution lies not only in the metacognitive awareness that a problem exists, but in the emotional interpretation that there exists a solution.

In a mathematics' classroom, students are often placed on a forked path where a problem is given and the solution must be found. The classroom experience as well is only fully captured when we expand our view of learning beyond one of pure cognition. The emotional experience of the classroom is shaped by students' beliefs, by what they attribute their academic successes and failures to, in turn affecting the paths taken, goals planned, energy expended, strategies used, and ultimately knowledge acquired.

Will students choose to become metacognitively engaged in seeking the problem's solution if they do not feel they have control over their own learning? The answer to this question can only be surmised based on the available research. Previous research indicates that children who attribute their learning to uncontrollable causes, such as a lack of ability, feel that failure is insurmountable and are not likely to choose the path of "knowing." Attributing failure to a lack of effort, on the other hand, empowers students to confront future challenges. The interplay between students' attributions, metacognition, and performance has been demonstrated during memory tasks and in reading. One purpose of this study was to extend this research into the area of mathematical problem solving. A second purpose of this study was to elaborate on prior attribution models which focus on ability, effort, luck, and task difficulty.

Mathematical problem solving is a domain in need of further examination into the role of attributions and metacognition. As Silver (1985) writes: "When students approach mathematical tasks, and especially those that are problematic, they do not enter the arena as purely cognitive beings. Students' behavior may be influenced by their feelings of self-esteem, their perceived control- or lack of control. . . . The notion of metacognition . . . may be a useful way of bridging the affective/cognitive chasm" (pp. 253, 254). In the same vein, McLeod (1985) writes: "If students attribute failure to solve a problem to their lack of ability . . . then the students' metacognitive choices may be severely limited. Such students will rarely use the wide range of heuristics that are available to them" (p. 275). While attributions to a lack of "ability" may be related to the activities of problem solving, attribution theory must go beyond identifying global self-referents and capture more distinct factors that occur within specific contexts of learning, such as the causal role of strategies. Students who recognized the causal role of strategies were expected to become more metacognitively engaged in a mathematical problem-solving task and be more likely to solve a nonroutine problem than those who attributed their performance to effort or unknown causes. Attributions were assessed using both forced-choice and open-ended arrangements.

To examine the relationship between metacognition and causal ascriptions, also considered was the metacognitive assessment procedure. Metacognitive activities were examined during problem solving. A key metacognitive process, one most indicative of effective learning at all ages, is regulation. Students may evaluate their cognitive progress, but not all students regulate their activity based on this evaluation. Students may sense disequilibrium, but a reconceptualization of the learning process can only occur when those preceding activities are taken to consciousness and then reenacted in a new light. As Piaget notes, "Taking consciousness is far from being a simple beam of light like a flashlight, which would simply let us see what couldn't be seen before, but without transforming anything . . . in fact, taking consciousness is a conceptual reconstitution of what the action did" (Bringuier, 1980, p. 89). Protocol analysis allows one to parse a learning process into cognitive and metacognitive episodes from which it then becomes possible to analyze those crucial decision points when students come to "take consciousness" (regulate), or not. Furthermore, the use of protocol analysis is advantageous over a questionnaire measure since it eliminates socially desirable responses. The use of strategies is not based on what students say they do, but is based on what students actually do.

The most intriguing aspect of this metacognitive process is that taking consciousness not only allows the learner to reflect upon traverses of the past, and perhaps to modify attempts, but ". . . taking consciousness also contains understanding: you know how you succeeded," or failed (Piaget cited in Bringuier, 1980, p. 90). A reconceptualization of the learning process entails incorporating actions into self-theories, i.e., theories which encompass notions of who or what was responsible for success and failure. Attributions, then, arise as an integral part of the metacognitive process; they are themselves of a "meta" nature. Here we bring into unity what has often been presented in disjointed fragments, the cognitive and affective spheres of learning.

In the first section of Chapter II, several theories of personal control will be reviewed emphasizing an attribution model that has particular relevance to the classroom setting. The second section will focus on the role of attributions in explaining academic performance. While research based on Weiner's model will be reviewed, alternative views will also be presented, stressing in particular the role of strategy and unknown attributions. In the third section, metacognition will be defined, and research on its relationship to achievement will be discussed. Fourth, the relationship between attributions and metacognition will be explored. Since most of this research has used reading or memory tasks, Chapter III is dedicated to exploring the theoretical and empirical reasons for studying this relationship within the domain of mathematical problem solving. The results of pilot testing will be discussed and a framework from which the present study was originated will be explicated.

Chapter II

Literature Review: Theories and Research on Personal Control, Attributions, Metacognition and Achievement

Theories of Personal Control

More than two thousand years ago, the Chinese philosopher, Confucius, recognized the idea of personal control when he said: "In archery we have something like the way of the superior man (sic). When the archer misses the centre of the target, he turns round and seeks the cause of his failure in himself" (Confucius, trans. 1993). American theorists have struggled with the concept of internality as an explanatory principle of human motivation. Rotter (1954) introduced internal-external locus of control to refer to one's controllability of reward outcomes. According to Rotter, a person who believes that desirable consequences are the result of internal causes rather than external causes, such as luck, will be likely to engage in those behaviors upon which the reward is contingent. This unidimensional model has proven misleading, however, since there are internal factors that are not perceived as controllable, such as ability. Individuals who attribute negative outcomes to a lack of ability may feel that positive outcomes are not within reach, and may avoid challenging tasks even when the reward is great.

According to Weiner (1979, 1985), while the locale of control, internal or external, is relevant, one must also consider the controllability and stability of causal referents. Four main causal factors are emphasized in this model- ability, effort, task difficulty and luck. Since task difficulty and luck are external referents, and by definition uncontrollable, the model places emphasis on the distinction between ability and effort. While effort and ability are both internal referents, effort is controllable and unstable whereas ability is an uncontrollable yet stable attribute.

The stability dimension is predicted to be most closely related to expectations. When success or failure is attributed to a stable cause, the person expects future success or failure, respectively. When attributions are made to unstable causes, such as luck, the person is less sure of what to expect.

In short, the model predicts that students who believe they are instrumental in their own learning attribute success to ability (internal, stable) and failure to lack of effort (internal, unstable and controllable). Guided by Weiner's model, most attribution research has limited students' choices to the four main causal factors (ability, effort, task difficulty, and luck) through the utilization of forced-choice arrangements. While these attributions are said to be among the most common factors given by students

(Weiner, 1984), Weiner admits that "research restricting causality to the four causes given above at times might give rise to false conclusions" (1979, p. 4). This foresight to the shortcomings of such methodological procedures appears to have been validated. For instance, open-ended attribution measures often reveal attributions to strategy (Fabricius & Hagen, 1984), and the occurrence of unknown attributions has also been documented (Connell, 1985).

Strategy attributions have recently received greater attention due to their internal, controllable nature. As Graham (1991) states: "attributions for failure to low effort are adaptive because effort is unstable . . . Therefore, any self-ascription perceived as unstable theoretically should have the same positive effects as lack of effort" (p. 19-20). Recent research suggests that strategy is perceived as less stable than effort (Hagen, Meyer, & Weinstein, 1994). Students seem aware of the effort they typically put forth in school; since strategies vary according to the demands of the task, they are perceived as less stable. Thus, strategy attributions may be more adaptive in accounting for failure than effort attributions. Recognizing when one did not use the right strategy is crucial for further learning.

In short, while effort and strategy attributions are both internal, controllable, and to varying degrees unstable, they can be distinguished on the basis of the outcome that each will yield. Effort implies quantitative change, or greater exertion; strategy implies qualitative change, or more effective learning. The adaptive function of effort rests on the assumption that trying harder improves learning. This does not seem to be an assumption to which most American students ascribe. Covington and Omelich (1984) argue that effort is a "double-edged sword." Their theory of self-worth postulates that there is a competing need to protect one's sense of competency, and that "effort also implies that the cause of failure is low ability" (p. 162). In considering both self-worth and attribution theories, the interaction between effort, the importance of the task, and the outcome is central in predicting both the emotional and cognitive consequences of effort expenditure. High effort leading to an unsuccessful solution places one's self-esteem at risk, when the task is perceived as important (Brown & Weiner, 1984). Students who come to expect failure may, in order to protect their self-esteem, exert low effort. High effort leading to success seems to infer little about one's capacity to perform a task or repeat an action.

The competition between effort and ability, which self-worth theory is based on, seems to occur before the fifth grade. In the early grades, effort is not differentiated from ability but implies ability or learning. By the fifth grade, high effort implies low ability (Nicholls, 1984).

One possible reason for the change is that feedback is no longer based on effort or mastery but becomes normative, based on how well one's peers are doing (Stipek, 1984). Tracking and ability grouping become common practice, and social comparisons are part of the competitive classroom (Ames, 1984; Ames & Archer, 1988). Ability is a salient characteristic by which students are judged and come to judge themselves; effort and strategy are secondary.

The occurrence of these trends in the American classroom, from mastery to performance goals, symbolic to normative feedback, effort to ability causality, seems in accord with societal goals. In the United States, ability, not hard work, is the hallmark of competition and individualism; performance, less so persistence, is rewarded. In Japanese societies, where cooperativeness is fostered, "competence is defined partly as talent or genius, but partly as the capacity for hard work and persistence" (Vogel, 1963, cited in Holloway, 1988, p. 329). It is not surprising, then, that Japanese teachers, mothers and students place significantly more emphasis on effort as causal to school performance while their American counterparts blame sources outside of the child's reach, such as the school, or sources over which the child has less control, such as ability (Hess & Azuma, 1991). Even at the college level, while American students are likely to attribute success to effort, Asian students see effort as important for both success and failure (Yan & Gaier, 1994).

The research cited above implies that students' attributions can be modified within the American classroom by emphasizing learning goals as well as performance goals, effort and malleable ability over fixed ability, processes of learning as well as outcomes of learning. Such changes to the structure and focus of classrooms may have positive impact on students' causal beliefs. Hayamizu and Weiner (1993) found that students who believed that ability was malleable and controllable, and those who felt their lack of effort was not stable, were more likely to have an achievement goal tendency, or a desire to advance their performance <u>and</u> their knowledge.

The key tenet here is that strategy use is also a causal antecedent to both learning and performance, and a modifiable aspect of the learning process. While many researchers have been concerned with the role of effort as a part of the learning <u>process</u>, strategies are also an integral part of the learning <u>process</u>. As Dewey (1938) states:

> The intensity of the desire measures the strengths of the effort that will be put forth. But the wishes are empty castles in the air unless they are translated into the means by which they may be realized (p. 70).

Strategies are the means, and strategy attributions seem particularly worthy of further investigation for several reasons. First, in fitting with Weiner's model, strategies are perceived as internal and controllable, and as less stable than effort. Second, strategy attributions seem to transcend the structure of the classroom. Ames and Archer (1988) found that strategy attributions were significantly related to students' scores on both mastery and performance goal scales, and Ainley (1993) found that end-of-the-year achievement depended not only on whether 11th-grade female students had an orientation toward mastery or performance but on the level of strategies they used. Third, attribution research offers its most direct application to the classroom when such research investigates effects on specific classroom behavior (Stipek & Weisz, 1981). Metacognitive strategy use is a classroom behavior that is not only related to achievement but may be related to strategy attributions. It has been found, for instance, that self-regulated learners are not only self-efficacious and able to select environments that optimize learning, but they also attribute their success and failure to strategy use AND engage in the planning and monitoring of their learning process (Zimmerman & Martinez-Pons, 1992).

In addition to strategy attributions, also not addressed by Weiner's model are unknown attributions. Connell (1985) has found that many times students cannot locate a cause of their success or failure. A student who responds to the question, "why do you think you failed the exam?," with the response, "I don't know," is not taking personal responsibility for his/her failure, nor is he/she attributing such failure to someone or something else. The response is made without referents. If conceived of as a continuous dimension of control, unknown attributions may represent an extreme lack of control whereas strategy attributions may represent an active response to cause-effect. From this perspective effort would be considered a more passive cause of performance than strategy yet more active than unknown control.

In brief, Weiner's model has been the basis for most attribution research. While ability and effort are "common referents" of academic success and failure, this finding may be the result of the restrictions imposed by forced-choice formats. This not only presents a concern for prior methodology but calls for a theoretical reconsideration of attribution models. Strategy and unknown control attributions are both powerful predictors of achievement and seem to be used by students in the context of specific tasks, yet neither has received the attention it deserves.

The Relationship between Attributions and Achievement

There is a wealth of evidence suggesting that children of varying ability or performance levels exhibit different attribution patterns, that is, cite different reasons in accounting for their performance. For instance, students who have experienced repeated failure in school attribute such failure to a lack of ability (Butkowsky & Willows, 1980), and may not attribute success to effort (Carr, Borkowski, & Maxwell, 1991). Successful students, on the other hand, attribute their failure to controllable aspects of the learning process, such as their effort (Butkowsky & Willows, 1980). However, the relationship between effort attributions and academic performance appears inconsistent (Menec & Schonwetter, 1994). In fact, effort as a causal explanation for academic performance may denote a more passive response to learning than ascriptions to strategy (Shapley, 1994). Self-regulated students attribute their performance to strategy use (Zimmerman & Martinez-Pons, 1992), and strategy attributions have a positive effect on persistence and future expectations (Anderson & Jennings, 1980), as well as on performance (Fabricius & Hagen, 1984). Some students are unable to attribute their performance to any one cause (Bethea, 1986; Connell, 1985).

Effort and ability attributions.

Butkowsky and Willows (1980) designated fifth-grade boys as either good, average, or poor readers based on a discrepancy score between the nonverbal intelligence test and the Comprehension subtest of the Gates-MacGinitie Reading test. The students were given either solvable or unsolvable reading-specific tasks (anagrams) or non-specific tasks (line drawings). Before engaging in each task, students were asked about their expectancy for success. Following the tasks, students' attributions were measured. Students were asked to attribute their success or failure to either ability, luck, task difficulty or effort. These researchers found that poor readers attributed success to external factors (luck, task difficulty) and failure to the lack of ability. They also displayed lower expectancies of success, persisted on the tasks for shorter intervals, and experienced negative expectancy shifts after repeated failures. Good and average readers attributed success to internal factors (ability, effort) and failure to the lack of effort.

Carr, Borkowski, and Maxwell (1991) found similar patterns. Third, fourth, and fifth graders from four midwestern school systems were designated as achievers or underachievers. Both groups were receiving C's and D's in reading but the underachievers were judged by their teachers as capable of doing better, and had a greater discrepancy score between intelligence and reading performance. Achievers were judged to be working to their capacity. Both groups of students completed the eight school-related items on the Krause Attribution Questionnaire. This measure includes the four predominant categories of attributions, though the researchers were only interested in effort and ability. Half the items were worded for success and the other half for failure. Two scores were calculated, according to outcome, based on the formula, 2E + 1/2A.

The data revealed no differences between the groups' attributions for failure. Since both groups of students were receiving C's and D's in reading this finding is not surprising. However, these results may have been confounded by the use of the above formula. Is failure twice lack of effort and one-half lack of ability? The ratio of attributions to effort or ability given by the achievers and underachievers was assumed. Nonetheless, differences were found for success outcomes. The achievers believed that effort was important for their success, or more precisely that success was twice effort and one-half ability; the underachievers did not.

Interestingly, Kurtz and Weinert (1989) found that while average junior high school students attributed success to effort, gifted students believed that their own ability was the cause of their success. For average students, it may be a realistic evaluation to attribute success to effort. For gifted students, ability attributions may reinforce their sense of perceived competence while effort attributions may undermine it. In mathematics, for instance, students who believe they are good at math attribute success to ability (Schoenfeld, 1989). Boys, in particular, have stronger math efficacy than girls (Pajares & Miller, 1994), and are more likely to believe that their ability is responsible for math success (Stipek & Gralinski, 1991).

The implication is that students should be trained to attribute their success to their ability, thereby facilitating their efficacy, perceived competence, and future expectancies. Schunk (1994a, 1994c) reports on years of research that has examined the effects of providing students with ability feedback. In brief, this research has found that ability feedback for success increases self-efficacy and skill more than effort feedback or combined effort-ability feedback. However, students who have prior learning difficulties tend to discount ability feedback when effort feedback is provided first. Ability feedback, then, must be credible to the learner. With learning disabled students, effort feedback for success, particularly early success, enhances self-efficacy and skill. Similarly, it seems that effort feedback must also be credible.

If this is the case, one would not *always* expect strong correlations between effort attributions and achievement. Wagner, Spratt, Gal, and Paris (1989), using the effort/ability scale of the Intellectual Achievement Responsibility scale with Moroccan children, found that students' scores on this scale accounted for only an additional 2% of the variance in fifth-grade reading achievement after background variables (father's occupation, parents' educational level, and language use of parents and children in the home) were accounted for, and by seventh-grade this scale accounted for an additional 6% of the variance. Two to six percent is not substantial, suggesting only a marginal relationship between reading achievement and causal attributions to effort and ability.

Menec and Schonwetter (1994) also did not find the relationship between effort attributions and achievement to be as predicted. Two hundred and ninety-nine undergraduates were classified as either failure avoiders or success oriented. The failure avoiders, as predicted, attributed failure to a lack of ability. This pattern of attribution was positively related to cognitive interference, or the tendency to be bothered by test-irrelevant thoughts, and negatively related to achievement, or course exam scores. Success oriented students, conversely, attributed failure to effort which was negatively related to cognitive interference; however, unexpectedly, this pattern was also negatively related to achievement.

A third study did not find support for the positive relationship between effort attributions and achievement. Justice (1994) had 327 undergraduate psychology students attribute their mid-semester performance to luck, effort, task difficulty, or ability. The correlation between semester end grades and attributions to ability (.34, $p < .01$) was significant, but grades were not significantly related to effort attributions.

In short, the last three studies mentioned (Justice, 1994; Menec & Schonwetter, 1994; Wagner, et al., 1989) reveal findings that are contrary to theoretical predictions; effort attributions are not always positively related to achievement. However, the results of these studies may not generalize beyond the samples used. First, all three studies utilized college students. Second, as Schunk's work illustrates, effort as a causal explanation is credible to learners with past histories of learning difficulties. The three studies cited did not include students with learning difficulties or prior academic failure.

Effort attributions, in addition to achievement, have been studied in relation to strategy use. Schneider, Borkowski, Kurtz and Kerwin (1986) found that fourth-grade American children tend to endorse effort as the causal factor most responsible for successful classroom performance, while German children ascribe to effort, luck and ability with equal probability. For failure, German children were twice as likely to choose luck as an explanation. The attribution style of the American children predicted their use of a cluster-rehearsal strategy. For the German sample, attributions did not predict strategy use although the German children were more "strategic" than the American children. The authors concluded that, "theoretically salient environment factors in the home and school need to be measured and then related to personal, motivational, and metacognitive factors to create more accurate comprehensive models of cognitive performance in different cultural settings" (pp. 333-334).

In a follow-up study these researchers examined whether classroom factors would help explain these cross-cultural differences in attribution style (Kurtz, Schneider, Carr, Borkowski, & Rellinger, 1990). American and German first through fourth-grade teachers participated in the study. The teachers completed two questionnaires: one assessing classroom instruction of strategies and metacognitive skills, the other assessing teachers' beliefs about children's performance, i.e., as a result of effort or ability. They found that American teachers endorsed effort for explaining their students' performance more than German teachers, and that while the American teachers reported teaching more metacognitive strategies, such as, monitoring and checking, the German teachers reported greater task-specific instruction, such as, elaboration, phonetic strategies, and recoding of information.

That German children were found to be more strategic than American children (Schneider, Borkowski, Kurtz, & Kerwin, 1986), may or may not be the result of instructional practices; this was not directly tested. Environmental factors may be important predictors of cross-cultural differences in attribution patterns; however, another interpretation of these findings is plausible. For instance, if strategy attributions had been included there may have been fewer between-group differences. It is quite probable that children who are more strategic, regardless of social or cultural background, are also more aware of the causal role of strategies. For German children "effort" may not mean "strategic effort," perhaps explaining why effort attributions did not predict strategy use for this group. In fact, a more recent study (Kurtz-Costes & Schneider, 1994), also using a German second and fourth grade sample, found that effort attributions for failure were not significantly related to language or math grades; higher achievers attributed failure to external factors. For these German children this functional self-protective approach for accounting for failure may be attributable to a history of "work ethic," discounting the credibility of a lack of effort but certainly not eliminating the role of strategies.

Strategy attributions.

The role of strategy attributions was recognized in a study by Fabricius and Hagen (1984). They were interested in predicting recall performance based on sorting strategy use and attributions made to the sorting strategy. First and second grade students were given a group of pictures that could be categorized in order to aid recall. Children were not explicitly taught to use a sorting strategy;

however, the task was structured so that sorting had a strong impact on the student's recall. In the first session, students were told to "put the pictures on the stands" and were asked a series of questions to elicit their use of a strategy. Students were then given a second trial in which instructions were used to elicit strategy use- "put the pictures on the stands, but do whatever you want to help yourself remember." In the third trial noncategorical stimuli were used. Questions eliciting attribution responses followed, specifically, "Was it harder, easier, or the same to remember the pictures this time? Why? How does (whatever the child identified in response to "why") work to make it harder (easier, same)?" In these first three trials, no actual test of recall was given. In session two, the same procedure was repeated and the child's recall was tested. Of the thirty-five students who thought the noncategorical task was more difficult, nineteen (54%) attributed such difficulty to sorting, or to the fact that the task did not allow them to use the sorting strategy. Furthermore, children who made sorting strategy attributions in Session 1 attempted to use sorting in Session 2, and sorting significantly predicted recall performance.

Strategy attributions seem to be related to persistence and future expectations, as well as task performance. A study by Anderson and Jennings (1980) illustrated that when adults attribute failure to strategy they are more likely to persist and expect future success than when failure is attributed to a lack of ability. In this study, attributions were manipulated by having a confederate influence the participants' decision about whether ability or strategy was responsible for their failure on a persuasion task. Participants had to persuade people over the telephone to make a donation for a blood drive. Some participants received no influence by the confederate, the No Attribution condition. In the No Attribution group, the outcome of the persuasion task was also manipulated and used as a baseline to estimate the effects of success and failure on this task. In the Attribution condition, all subjects failed. Subjects were asked to make short and long term predictions of their future success at persuading, and were asked to estimate how practice at the task would improve their performance.

The results showed that strategy subjects were more likely to expect future success than ability subjects. Furthermore, strategy subjects, even though induced to fail, had future expectations almost as high as successful No Attribution subjects and believed that practice would improve performance. Conversely, subjects who attributed their failure to their own lack of ability at persuasion did not believe that failure was surmountable.

These results are not surprising given that ability is perceived as an uncontrollable cause, whereas strategy is controllable. The differential effects of ascribing to effort or strategy has not been a prediction of prior attribution models since both are internal and controllable factors. However, differences have been found. Zimmerman and Martinez-Pons (1986) developed an open-ended structured interview, the Self-Regulated Learning Interview Schedule (SRLIS), to assess students' use of fourteen self-regulated learning strategies. They found that high school students in a high achievement track attributed their academic standing to the use of strategies more than similar students in a regular achievement track. Interestingly, students in the high track were not only more strategic but did not agree with statements emphasizing the role of effort, such as, "If I am having difficulty motivating myself to complete my homework, I just work harder," as frequently as did regular track students.

Shapley (1994) supported these findings. Sixth-grade students in one suburban Texas school participated in a strategic thinking course emphasizing critical thinking and problem solving, and stressing self-regulatory behaviors, such as planning and tracking assignments. Similar students from a second school served as the control group. Using the SRLIS developed by Zimmerman and Martinez-Pons (1986), strategy use and strategy frequency were assessed. In addition, students' theory and confidence of intelligence were measured. Students who ascribed to a malleable, rather than fixed, view of intelligence should be more confident in their abilities and thus more likely to self-regulate. Experimental subjects having had the critical thinking experience should be further advanced in their capacity to self-regulate and should be more likely to adopt the belief that ability undergoes developmental change with the attainment of new skills and knowledge. The prediction was not supported; theory of intelligence seemed unaffected by experimental procedures. However, as most relevant to this discussion, mean difference tests showed that treatment subjects reported more frequent use of self-evaluation, organizing and transforming, goal setting and planning, and keeping records and monitoring. Control group subjects reported more non-self-regulated strategies, such as, "I try to do the best I can" or "I try to remember." That experimental subjects learned to be more strategic yet this did not appear to alter their view of ability may be a result of the Theory of Intelligence measure. The items on this Henderson and Dweck (1989, cited in Shapley, 1994) measure are not situationally specific, e.g., "You have a certain amount of intelligence, and you can't do much to change it." Believing that one's intelligence is malleable may depend on the domain to which it applies. While a student may believe s/he has the capacity to learn history, for instance, s/he may not hold a similar conviction in mathematics. Social cognitions need to be assessed with reference to specific learning contexts.

Clifford (1986) further demonstrates that while both effort and strategy are internal, controllable factors, there is reason to separate the two. In this study, attributions were manipulated and used to predict affect, attitude, and future performance. Fifty-four liberal arts' college teachers and fifty female undergraduates were given a hypothetical scenario of a college student whose first semester grade point average was 1.8. Subjects were either told that the student's performance was a result of high effort/low strategy or low effort/high strategy. Based on this information, the subjects were to rate the hypothetical student's feelings about college, attitude toward college, and future performance in college. Both students and teachers perceived the student's attitude and chances for future success to be enhanced when failure was attributed to ineffective strategies, as opposed to a lack of effort.

The strategy attribution studies cited in this section are interesting in light of the past emphasis given to attributions of ability, effort, luck, and task difficulty. Students attribute performance to many different causes depending on the particular learning context. Assessment procedures are needed which account for the diversity of learning experiences. Rohrkemper (1986) states that students' attributions, when measured "in action," that is, is, during problem solution, may differ than when assessed in relation to past performance or a hypothetical situation. In fact, research which does not limit or force students' choices into particular causal categories and links causal beliefs to a specific task more typically finds attributions to strategy than to effort or ability (Fabricius & Hagen, 1984; Fusco, 1993).

Fusco (1993) administered an open-ended attribution questionnaire to 48 sixth graders, 39 high school students, and 22 undergraduates. All students completed the questionnaire in their math class. The most frequent reason given for success and for failure in mathematical problem solving for all three groups was problem solving strategy, for example, "I was able to solve the problem because I followed the right procedure." Out of the total number of attribution responses for success, 35%, 32%, and 42% (for sixth-graders, high school students, and undergraduates, respectively) made reference to a problem-solving strategy. Of the attributions to failure at a problem-solving task, 34% and 37% of the responses were classified as strategy attributions for high school and college students, respectively. (Sixth-graders were omitted due to a sample of five who reported failing the task.)

With increased attention to the processes of learning comes increased awareness and recognition in the role of strategies. Thus, strategy attributions may be more directly related to a "perceived self in action" while effort attributions may be more closely tied to global performance. If attributions, then, are assessed with open-ended formats, new light may be shed on the types of causal factors students use to judge their achievements.

Unknown control attributions.

While some students may cite a specific cause for their success or failure, such as, strategy, effort, or ability, other students acknowledge that they do not know what was responsible for their performance. Connell's (1985) Multidimensional Scale of Perceptions of Control includes three dimensions of control (Unknown, Internal, and Powerful Others) across four domains (Social, Cognitive, Physical, and General). Using 1,300 third through ninth graders from New York and California, he found that the Unknown subscale was most significantly related to standardized achievement (negatively), and that this pattern held for both boys and girls. Unknown control was also negatively related to teacher ratings of cognitive competence.

Bethea (1986) utilized Connell's scale with 7th and 8th graders from a New York inner-city school, and found that the Unknown subscale yielded the strongest results. Specifically, in the cognitive domain, only unknown control was significantly related to end-of-the-year grade point average (negatively), for both boys and girls. Unknown control also had the only significant relationship to Achievement Reading Test (ART) scores and Achievement Math Test (AMT) scores, with a few exceptions. For girls, Internal control was positively related to ART scores. For boys, Internal control was positively related to AMT scores. Though perceptions of control to Internal or Powerful Others varied depending on gender and subject area, attributions to Unknown control were consistent for boys and girls, for general academic achievement (GPA), and for standardized measures of reading and math. It is worth mentioning that academic achievement was more strongly related to attributions in the Social and Cognitive domains than in the Physical and General domains. Attributions within a specific subject area, such as mathematical problem solving, should be even more closely related to achievement in that domain.

Implications.

Attribution research has largely focused on the effort/ability distinction. Many have hypothesized that better students recognize effort as causal to their academic performance. The implication is that attribution retraining should focus on the role of effort, particularly in accounting for failure. However, the linearity between effort and performance cannot be assumed. Effort feedback does not provide students with specific information necessary for conceptual change. Telling a low-achieving yet striving student to "try harder" may only be appropriate under certain conditions (Schunk, 1989). As Schunk (1994a) states: "Given that teachers teach strategies and that strategy use is controllable by students, strategy attributions are apt to facilitate self-efficacy, motivation, and learning" (p. 92).

A particularly appealing prospect for diminishing gender differences in mathematics and boosting the math efficacy of girls would be to provide strategy feedback, particularly since strategy use is related to the types of social cognitions which explain such gender differences. The caveat in the appeal for strategy-based intervention is in the types of strategies to which students attend. Gallagher and DeLisi (1994) have found that high school girls are less confident in their math abilities and more likely to use conventional strategies to solve problems, e.g., algorithms, whereas boys have greater mathematical confidence and opt for unconventional strategies, such as those involving logic and insight. That girls are socialized to be rule-dependent while boys are trained for independent and autonomous thinking is not newly informative (Tittle, 1986), but a finding that never ceases to raise the empirical brow. As Tittle (1986) argues, "Social cognitions are being more precisely defined in relation to specific learning behaviors . . . these behaviors appear to be modifiable through teacher intervention and self-awareness or regulation of behavior" (p. 1166).

The specific learning behavior relevant to the present investigation is metacognition, or cognitive control, which is expected to be related to attribution beliefs. Before reviewing this research, metacognition is defined, and research describing the direct relationship between metacognition and performance is discussed.

Metacognition

Definition.

Metacognition has been defined and examined according to two aspects, one as a knowledge state and the other as an active state. The first is commonly referred to as thinking about thinking, or as an individual's knowledge of his/her own cognitive processes that develops with age and experience (Flavell, 1985). Metacognitive knowledge may include specific or general strategy knowledge (Borkowski & Kurtz, 1987), knowledge of situational variables (Miller, 1985), and knowledge of people and self as cognitive processors (Flavell, 1979).

Metacognitive knowledge implies an awareness of that knowledge. Subjects are required to verbalize, for instance, why certain strategies may be more effective for solving math problems (Carr, Alexander, & Folds-Bennett, 1993). Verbal reports have a distinct disadvantage with young children who have limited verbal fluency (Garner & Alexander, 1989). Even for older students it may be difficult to determine whether metacognitive knowledge predicts what students will DO while cognitively engaged. Often knowledge remains isolated; is stored in its original form, tied to the context within which it was first learned. Until a level of consciousness emerges, such knowledge remains inert and is not translated into action. In fact, 'experts' have a knowledge base that is usable because they are able to recognize when there is insufficient information to solve a problem and are able to "debug" their learning attempts (Bransford, Sherwood, Vye & Reiser, 1986). Debugging refers to the second definition of metacognition, or metacognition as an active state.

Whereas cognitive strategies are employed to make cognitive progress, metacognitive strategies are employed to monitor cognitive progress. Analogous to Piaget's concept of performing operations on operations, cognitive monitoring encompasses the activities of evaluation and regulation (Jacobs & Paris, 1987). For instance, the reader becomes aware of his/her lack of comprehension. Recognizing this state of 'not knowing,' the reader may regulate his/her attempts by rereading the passage. In short, evaluation precedes regulation. Regulation allows the learner to rectify "not knowing." Students will not realize the necessity for rectification unless they recognize that their initial attempts have been futile, unless they have been monitoring their cognitive progress.

> Do you suppose then that he would have attempted to look for, or learn, what he thought he knew (though he did not know) before he was thrown into perplexity, became aware of his ignorance, and felt a desire to know? (Plato, trans. 1971, p. 39)

In short, metacognition can refer to the knowledge of, or the monitoring of, cognition. Metacognitive activities may be better predictors of performance than metacognitive knowledge. For instance, Borkowski, Carr, Rellinger, and Pressley (1990) found that reading awareness (metacognitive knowledge) did not differentiate reading achievers from underachievers, and Wagner et al. (1989) found that only extreme scores on reading awareness were related to reading performance. Conversely, Zabrucky and Ratner (1989), when measuring metacognitive activities, did find metacognitive differences among good and poor readers, as will be discussed in greater detail in the following section.

Metacognitive activities may also be more closely related to the motivational aspects of learning than metacognitive knowledge. Pintrich and Schrauben (1992) state that while attributions are probably indirectly linked to metacognitive knowledge, it is likely that such motivational factors will be directly linked to the self-regulation of cognition, or the evaluating and regulating of one's thought processes and behaviors. For the purposes of the present study, then, metacognition will be defined according to specific monitoring behaviors or activities.

Metacognition and Achievement.

In the academic arena, students confront situations that can either lead to new learning experiences, or can result in frustration and often failure. Effective learners are often successful because they monitor their learning attempts. For instance, good readers are more likely to employ regulatory strategies to "fix" comprehension than poor readers. This pattern has been found for sixth-graders (Zabrucky & Ratner, 1989), junior high school (Pintrich & DeGroot, 1990) and college students (Goetz & Palmer, 1984).

Zabrucky and Ratner (1989) designated sixth-grade students as good or poor readers based on their reading scores on the Iowa Basic Skills Test. Eight stories, with four versions of each story, were used to assess comprehension monitoring. Each version differed by only one sentence, the context sentence. The context sentence in relation to the target sentence was either factually congruent or factually incongruent, and the distance between the context and target sentences was either close or far. Each student read all eight stories, but only one version. Children were instructed to understand the story "the best they could." Reading times were recorded for incongruent and congruent sentences. After reading a story the subjects were asked to recall the story in their own words, and to determine if the story made sense. The correct answer was "yes" for congruent versions and "no" for incongruent versions.

The results indicated that both good and poor readers took more time to read incongruent statements. However, in the Close condition, only good readers gave more correct responses to the question, "did the story make sense?". Not only did good readers evaluate their comprehension (recognize the incongruencies), but they also engaged in more look-back or regulatory strategies than did poor readers. In relation to performance on the specific task, good readers recalled more context sentences and incongruent target sentences than poor readers.

Pintrich and DeGroot (1990) found similar relationships with junior high school students from eight science and seven English classes. Achievement was measured by first and second semester grades. Metacognition was measured by a self-report questionnaire, the Motivated Strategies for Learning Questionnaire (MSLQ), which contained items on motivation (self-efficacy, intrinsic value, and anxiety), cognitive strategy use (elaboration, rehearsal, and organization study strategies), metacognitive strategy use (planning, skimming, and comprehension monitoring), and management of effort. Metacognitive strategy use and management of effort formed one scale called Self-Regulation.

The results showed that 1) prior achievement predicted Self-Regulation but not cognitive strategy use, 2) high achieving students were more likely to agree with self-regulatory statements such as, "I ask myself questions to make sure I know the material I have been studying," and "Even when study materials are dull and uninteresting, I keep working until I finish," 3) students high in self-efficacy were more likely than those low in self-efficacy to report using both cognitive and metacognitive strategies, 4) self-efficacy was related to achievement, 5) the use of self-regulatory and cognitive strategies significantly predicted achievement, and most compelling, 6) Self-Regulation was the best predictor of achievement. The results can be summarized as follows:

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Prior achievement  →  Self-regulation →  Achievement
                            ↑                 ↑
              Self-efficacy  →   Cognitive strategies
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Goetz and Palmer (1984), using 224 undergraduate students from a study skill's course, were interested in the relationships between cognitive and metacognitive strategy use, and reading performance. Reading performance was measured with four short-answer questions following each reading passage. Strategy use was measured with a self-report questionnaire. They found that of eighteen reading study strategies, four predicted 33% of the variance of short-answer performance. These four were "skim the passage," "think about how you'll be tested," "when you don't understand . . skim ahead for clarification," and "go back and reread." That these last two regulatory strategies accounted for unique variance in actual task performance supports the link between metacognitive strategy use and reading performance. The next section discusses the link between metacognition and attributions.

The Relationship between Attributions and Metacognition

As Socrates explains to Meno:

> nor (would he seek) what he does not know, for in that case he does not know what he is to look for (Plato, trans. 1971).

One may not know what to look for but the realization of not knowing engenders the potential birth for new learning. The first step toward conceptual change is dissatisfaction with existing ideas, usually arising out of a discrepancy between one's prior knowledge and a new experience. For learning to occur, accommodation must take place cognitively and emotionally. A conscious evaluation of skill and efficacy as well as a belief in the developmental nature of learning is required. If students do not believe they can change the direction of a particular learning experience, i.e., through the use of strategies, they may not be willing to resolve discrepancies. Certain attribution beliefs may reflect the belief that change is possible and thus may predict those metacognitive activities which promote learning.

Diener and Dweck (1978) examined metacognitive, cognitive, and motivational differences between helpless and mastery-oriented fifth-grade children. Using only effort items for failed outcomes, the child's orientation was determined from scores on the Intellectual Achievement Responsibility Scale. Children who attributed failure to their own lack of effort were considered mastery-oriented; those who did not were deemed "learned helpless."

Subjects were given a visual discrimination task in which each stimulus card consisted of three dimensions (shape, color, and symbol). One or more dimension was manipulated on each trial and the task was to test various hypotheses concerning these manipulations. The task was structured so that all hypotheses would be incorrect and subjects were given negative feedback on every fourth trial. During each trial, students were asked to talk-aloud as they were working through the task. After twenty trials the subjects were asked, "why do you think you had trouble with these problems?" The response to this question differed among the two groups of children. Over 50% of the helpless children attributed their performance to a lack of ability whereas none of the mastery-oriented children made this attribution. Results from the talk-aloud procedure showed that not only was the hypothesis testing of the mastery-oriented children more effective but the effectiveness of strategies declined over trials for the helpless children. Most relevant to this discussion was the finding that mastery-oriented children did not make verbal attributions but were engaged in monitoring the strategies they used. They seemed "less concerned about the cause of their failures than they were with a remedy for the failure" (p. 459).

Whether the lack of verbalized causation for mastery-oriented subjects reflects an absence of causal search has been questioned. Weiner (1979) disagrees, commenting that ". . . I suspect that attribution influences often are quite retrospective . . . take place below a level of immediate awareness . . . Thus I believe that attributions are supplied by mastery-oriented children, as well, although not necessarily during or immediately following all task performances" (p. 4). When the search for interpretation occurs is open for debate, though Weiner (1985b) postulates that causal search is elicited by an unexpected event, nonattainment of a goal, when the task is valued, and when information pertinent to a sense of self is salient. For some students this search may not be elicited until even the change in one's solution path was not fruitful.

The Diener and Dweck study, while suggesting a link between prior attributions and cognitive monitoring, is subject to the criticism of all correlational studies-- a third variable may exist. For instance, prior knowledge or ability may predict cognitive monitoring, perhaps to a greater extent than one's causal beliefs. However, ability, if defined as a capacity to learn, requires metacognitive acumen. Ability encompasses the metacognitive processes by which knowledge is acquired. "When you know a thing, to hold that you know it; and when you do not know a thing, to allow that you do not know it; -this is knowledge" (Confucius, trans. 1993, p. 40). Furthermore, and perhaps more importantly, unlike ability, attributions are subject to change and can be modified to yield gains in performance.

The strongest support for the effects of attributions on strategic behavior and attitudes comes from training studies. Although the results are mixed, they are quite revealing. The key question addressed by these studies is whether attribution training enhances the effects of metacognitive strategy training for improving performance. Two studies found that attribution training did <u>not</u> increase performance over and beyond that of metacognitive training; however, there were methodological limitations in both studies. In the first study, Short and Ryan (1984) found no differences between strategy-trained and strategy-plus-attribution trained groups on reading performance or metacognitive measures. However, the validity of the training can be disputed. For instance, the attribution training consisted of the following five self-statements: Enjoy the story, Praise yourself for a job well done, Try hard, Think of how happy you'll be when you're doing well on the test, and Give yourself a pat on the back. These statements seem to deal with changing affect rather than changing attributions. While a positive emotional experience is certainly relevant to the prediction of motivational attributions, feedback, such as "Give yourself a pat on the back," would only produce a sense of accomplishment if the student has already made a causal connection between strategy-based efforts and performance.

Walker and Debus (1988) also did not find benefits of adding an attribution component to metacognitive training, a reciprocal teaching method, for fifth-grade children. Again, this may be due to the inefficiency of the attribution component. Children were given attribution feedback such as, "Good, you certainly have the ability to do this and you're trying very hard" (p.4). It is questionable what the effects of simultaneous ability and effort attributions would be. Schunk (1989) states ". . . effort feedback for early successes is more credible . . . As students develop skills, switching to ability feedback enhances self-efficacy better" (p.12). Also feedback was given to the group, as well as to each individual. Attributions given to the whole group may have devalued individual attributions. A third, and most probable, explanation is that reciprocal teaching emphasizes metacognitive reading strategies and may be a sophisticated and efficient method for altering attributions without directly aiming to do so. Since both conditions received this strategy training it is likely that the attributions of both groups were affected so that the attribution component was not additionally advantageous.

While Short and Ryan (1984), and Walker and Debus (1988) did not find positive gains due to attribution training, there is also evidence to the contrary. Attribution training can enhance the effects of metacognitive strategy training when the former has been developed from a sound theoretical basis. A study by Kurtz and Borkowski (1984) tested differences among three treatment conditions: 1) metacognitive and strategy training, 2) metacognitive training only, and 3) strategy training only. The strategy training encompassed direct instruction and modeling of rehearsal, clustering, and checking strategies. The metacognitive training served to increase metamemorial <u>knowledge</u> by giving feedback about the instructed strategies' effectiveness, and did <u>not</u> teach metacognitive strategies, such as monitoring. The fact that the metacognitive training did not increase recall performance or strategy scores, then, was not surprising. Providing students with more knowledge does not necessarily result in a greater capacity to utilize such knowledge.

While the main focus of the Kurtz and Borkowski study was on the effects of metacognitive training on recall performance and strategy use, another finding was its effect on the attribution beliefs of first and third grade children: ". . . children in the strategy-trained groups who attributed success to effort were significantly more strategic at maintenance and generalization than children who attributed success to ability and task characteristics. . ." (p. 349). These findings have led to hypotheses about the effects of specific attribution retraining.

Reid and Borkowski (1985, cited in Borkowski, Weyhing, & Turner, 1986) randomly assigned learning disabled and hyperactive children to either an Executive condition, an Executive plus Attribution condition, or a Control group. Those in the Executive condition received specific strategy instruction and general self-control training for paired associate and sort recall tasks. Those in the Executive plus Attribution group received specific self-control training designed to help children make the connection between their strategic behavior and successful performance. The validity of the attribution training is illustrated by the fact that changes in attributions persisted over a 10-month period. Attributions did not change for those in the control or Executive conditions, implying that strategy training alone was not sufficient for altering attribution beliefs.

Furthermore, unlike in the Kurtz and Borkowski (1984) study, strategy scores on a transfer task were significantly higher for the Executive-plus Attribution group than for the other two groups. It seems that strategy use does not depend on increases in metamemorial knowledge, (Kurtz & Borkowski, 1984), but can be improved with specific strategy instruction and attribution retraining. This was confirmed by Kurtz (1989). Continuing this line of research in the area of memory, 56 learning disabled students from a private elementary school in France were randomly assigned to the three conditions. Again the strategy-plus-attribution condition was most effective for increasing memory performance and strategy use, and these results transferred to new tasks. Again no changes in metamemorial knowledge were evident from pre to post-testing, thus, the results could not be explained from increases in metamemorial knowledge.

This research has been replicated in the area of reading. Weyhing (1986, cited in Borkowski, Weyhing, & Turner, 1986), using the same procedure as Reid and Borkowski (1985), found similar results. Learning disabled children who received attribution training, in addition to strategy training, had significantly higher comprehension strategy scores on a summarization task than did either of the two control groups. Furthermore, Borkowski, Weyhing, and Carr (1988) found that the effects of this comprehensive training program generalized to the inferential subtest of the Stanford Diagnostic Reading test for the strategy-plus-attribution group. Finally, Borkowski, Carr, Rellinger, and Pressley (1990) not only found that the strategy-plus-attribution group produced gains in strategy use, recall, and attribution beliefs, but the effects generalized to classroom performance with an increase in reading grades. The most striking result of this latter study was that while the strategy training alone was sufficient for producing gains in metacognitive knowledge, only the addition of attribution training increased performance and strategy use.

In summary, when designed appropriately, attribution training enhances the effects of metacognitive and strategy training for increasing strategy use, and for improving standardized test scores and classroom grades. It is important to note that Borkowski and his colleagues have developed a comprehensive attribution program that is geared toward changing antecedent attributions, as well as program-specific attributions, and includes discussion, reflection, and feedback about the reasons for successful or unsuccessful outcomes. This feedback may be the largest contributing factor to the effectiveness of the training. Though these researchers assessed attributions to effort, luck, ability, and task difficulty, the attribution training stresses that trying hard "in this case meant using the strategy" (Kurtz, 1989, p. 4), and reinforces "the need for effort in the form of attentiveness to the strategy" (Borkowski & Thorpe, 1994, p. 58). Furthermore, Pressley, Borkowski, and Schneider (1987) define a "good strategy user" as one who "possesses the general understanding that good performance is tied to effort, particularly effort expended in carrying out appropriate strategies" (p. 91). The emphasis is not on effort but on strategy; these researchers have not measured strategy attributions.

A recent research study, following the Borkowski et al. model, tested the effects of attribution and strategy training with students with mild to moderate mental retardation (Turner, Dofny & Dutka, 1994). During rehearsal training, strategies were modeled and then students used the strategies with prompting. Students either received strategy training alone or in conjunction with attribution training. Some students received only the attribution training. There was also a No Treatment group. The dependent measures were study time and recall accuracy. They found that at maintenance, strategy training and strategy-attribution training were equally more effective than attribution training alone for both study time and recall accuracy. At transfer (conducted two to four days after training), only the strategy-attribution group maintained its' advantage on both outcome measures over the attribution-only and control groups. The strategy training group was not significantly different from any other group.

What seems striking is that while these researchers do not discuss "strategy attributions," the strategy and attribution combined training emphasized that "effort was necessary for successful strategy use" (p. 449). This conditional feedback appears different from that in the Attribution condition in which students were "instructed to try hard to remember as many pictures as possible" (p. 449). Whether this difference in wording was actual or a function of the variability in written expression is hard to say, but the authors do conclude, "We attribute this longer study and greater accuracy to the students' understanding that strategy use was within their control" (p. 453).

Strategy Attribution Training.

The effects of strategy attribution training have been directly addressed in only four studies (three of which were published in 1994) with different age groups, different tasks, and different outcomes. Ghatala, Levin, Pressley and Goodwin (1986) used a second-grade sample and were concerned with the effects of memory training; Fulk (1994) worked with learning-disabled adolescents on spelling instruction; Hagen, Meyer, and Weinstein (1994), and Perry and Struthers (1994) both involved college samples in learning and study strategies, respectively. However, the former only measured changes in the stability of attributions and the occurrence of strategy attributions.

Ghatala, Levin, Pressley, and Goodwin (1986) randomly assigned second-graders to one of four conditions: zero, one, two, and three-component training. Students either received explicit strategy information or strategy-monitoring training. That is, students were either told that repetition is a more effective strategy than letter-search or they had to monitor the effectiveness of these strategies, thus deriving the information on their own. The three-component training consisted of Assessment, assessing changes in performance while varying strategies; Attribution, attributing changes to the strategies; and Selection, using information gained from assessment to select the best strategy for the task. The two-component training involved Assessment and Attribution while the one-component training involved only Assessment. The zero-component served as a control. There were eight groups in total.

The hypotheses were that the additional components would provide the greatest strategy information, and that strategy-monitoring would be less effective than explicitly providing children with strategy information. These hypotheses were supported. Students in the three-component training selected the repetition strategy over the letter-search strategy and attributed their performance to this strategy more than control subjects regardless of whether they received monitoring or explicit information. The two-component condition was also more effective in eliciting strategy attributions than one or zero-component conditions, however, only the subjects who received explicit instruction selected the more appropriate strategy. While the inclusion of the Selection component was not required to alter attributions, "selection" was necessary in order for the students to become metacognitively aware of the role of certain strategies and to subsequently select the appropriate one. That is, "only when the training provided practice in attributing changes in performance to strategies <u>in order to select the more effective strategy</u> were children able to derive and capitalize on strategy-utility information to guide their strategy choices in a subsequent learning task" (p. 90, underline added).

While this finding may be true of second-graders, older students can derive strategy information from monitoring their strategy use. That is, they may not need explicit guidance "to select the more appropriate strategy." Thus, as the metacognitive system develops, the relationship between strategy attributions and strategy use should grow stronger.

Fulk (1994) had three conditions: a spelling strategy condition, a spelling plus attribution training condition, and a traditional control condition. Spelling strategy instruction included following five steps: say the word, write and say the word, check your spelling, trace and say the word, and write the word from memory and check it. Attribution training began with explicit instruction about the relevance of effort. During the training, feedback on effort and effective strategy use was provided for successes. Students were also asked "Why do you think you spelled that word correctly" and were told "Right, you tried hard, used the study strategy, and spelled the word correctly." Following failure, students were reminded to try hard and use the study steps. Spelling accuracy, study time, strategy use and attributions were measured. The attribution measure included vignettes which required students to attribute success or failure to effort, luck, task difficulty, ability, or help (strategy attributions were not included). These researchers found, not surprisingly, that there were no significant differences between the groups on spelling performance, study time, strategy use, or posttest effort attributions. The results were explained as due to small sample sizes (N=43) and large pretest spelling variability. Another possibility is that since the strategy training did not improve performance overall, presumably the strategies were ineffective. Students may have discounted attributions to strategy. Furthermore, the effects of combined effort and strategy attributions are in need of further study.

Hagen, Meyer, and Weinstein (1994) conducted a strategy intervention study with 75 college students enrolled in a learning strategies course. Students were "taught attribution theory in connection with strategy instruction" (p. 3). Attributions were measured by having students openly respond to two hypothetical academic events that had negative outcomes. The two items were based on the Attribution Styles Questionnaire yielding composite attribution dimension scores for internality, controllability, and stability. Students' responses were also categorized as strategy versus non-strategy attributions. The only significant change in attributions after the intervention was on the stability dimension. Students perceived the cause of negative events as less stable at post-testing, however, they did not report more strategy attributions. Interestingly, students distinguished the stability of effort and strategy; at both pre- and post-testing, strategy was viewed as less stable than effort.

Although providing important insight into the distinctness of students' perceptions of strategy and effort, this study did not support the hypothesis that strategy training increases attributions to strategy. However, the intervention procedures were not described in this report and it did not seem that any specific instructor training was incorporated. Furthermore, no outcome measures were included making it difficult to determine whether those students who did make strategy attributions were more successful in the learning study course.

Perry and Struthers (1994) illustrate the effects of attribution retraining with 318 introductory psychology college students. The training involved a control and three attribution conditions: handout only, videotape only, and videotape plus discussion. In the videotape component, participants watched two students discuss why they did poorly on a test. These students attributed their failure to lack of effort and poor study strategy. In the videotape plus discussion group, the attribution component was more personal, that is, based on the students own experiences. It was predicted that attribution retraining would be most effective for students with low perceived success. They found that only students in the videotape plus discussion group who had low perceived success did better on a course exam and had higher grades in the course, relative to the control group. These results remained significant even when prior test performance and high school GPA were used as covariates. Attribution retraining was effective when personalized, when strategy and effort attributions were instilled, and for students who had low perceived success.

Summary

One of the main premises of attribution theory is that students who believe they have control over their learning, that is, who believe that their "efforts" will yield success, are likely to be motivated to succeed, persist in the face of failure, and achieve more than students who feel that learning is beyond their control. The research supporting this claim is based on comparisons between successful and unsuccessful learners, and suggests that the former are more likely to attribute success to ability (Kurtz & Weinert, 1989; Schoenfeld, 1989) and effort (Butkowsky & Willows, 1980; Carr, Borkowski, & Maxwell, 1991) and failure to a lack of effort (Butkowsky & Willows, 1980). The use of forced-choice attribution measures which restricts causality to ability, effort, luck or task difficulty limits the comparisons that can be made. Studies that use open-ended measures indicate that students often attribute success and failure to strategy (Fabricius & Hagen, 1984; Fusco, 1993) or are unable to locate a cause for their performance outcome (Connell, 1985). Unaccounted for, then, by most attribution research are attributions to unknown causes and strategies. Research that has documented the importance of unknown control suggests that this attribution pattern is negatively related to standardized achievement, teacher ratings of competency (Connell, 1985) and grades (Bethea, 1986). Strategy attributions are positively related to strategy use (Fabricius & Hagen, 1984), persistence (Anderson & Jennings, 1980), and self-regulation (Zimmerman & Martinez-Pons, 1986, 1992). Although strategy and effort are both perceived as internal and controllable causes, research indicates that there is just reason for separating the two or for expecting differences between strategy and effort attributions (Clifford, 1986; Shapley, 1994; Zimmerman & Martinez-Pons, 1986, 1992), particularly as related to metacognitive or regulatory processes.

Metacognitive regulation, in particular, the activity of rectifying one's cognitive errors, is characteristic of more successful learners (Pintrich & DeGroot, 1990; Zabrucky & Ratner, 1989), and may be related to attribution patterns (Diener & Dweck, 1979). Training research provides the most direct evidence that metacognitive strategy training in conjunction with altering students' attributions has a direct impact on strategy use and performance (Borkowski, Carr, Rellinger, & Pressley, 1990; Borkowski, Weyhing, & Carr, 1988; Kurtz & Borkowski, 1984; Turner, Dofny, & Dutka, 1994). The effectiveness of this training may be the result of teaching students effective strategies and raising their awareness of the causal impact that strategies have on performance and learning. In fact, strategy attribution training is promising when the strategy training itself is comprehensive (Ghatala, Levin, Pressley, & Goodwin, 1986).

Combined strategy and effort training seems less effective (Fulk, 1994) or may be appropriate for those with low perceived success (Perry & Struthers, 1994).

One caveat of the above research is that most studies assess metacognition with self-report questionnaires. The use of self-report questionnaires for measuring metacognition is a typical procedure, but not one that has gone unscrutinized. Pintrich and DeGroot (1990) review the limitations of self-reports and suggest that "the results need to be replicated with other measures, such as think-aloud protocols . . . " (p. 38). Research in the area of mathematical problem solving typically uses protocol analysis to assess metacognitive processes, an important distinction to the methodology of the present study.

The research presented thus far demonstrates the relationships between attributions, metacognition, and performance on reading, memory, visual discrimination, and study tasks. The same pattern of relationships should occur during mathematical problem solving. Mathematics, unlike many subjects, is one where affect is clearly attached (McLeod, 1985, 1991; Schoenfeld, 1989). The next chapter presents theoretical and empirical support for this hypothesis.

Chapter III

Research in Mathematical Problem Solving

Overview

Problem solving has typically been defined as involving problem comprehension and problem solution, and may include the monitoring of problem solving processes (see Randhawa, 1994). Motivational variables while seen as related to problem solving are rarely included as an integral aspect of this process. However, in the domain of mathematical problem solving the interplay between students' beliefs and their cognitive and metacognitive choices is particularly illuminating. Students bring to the problem-solving context not only their beliefs about themselves as learners and mathematicians but their beliefs about the domain of mathematics. Self-beliefs and context-beliefs seem co-dependent. Unfortunately, mathematical problem solving may not be viewed as a process of scientific inquiry where conjectures are tested and patterns observed (Schoenfeld, 1992). Rather, college students expect word problems to be solvable by step-by-step procedures that should take no more than twelve minutes to solve before being judged impossible (Schoenfeld, 1989). The problem is expected to be easily mastered with little effort, otherwise it is deemed impenetrable. Given this perception of problem solving, one would not expect high levels of confidence or high levels metacognitive engagement. As Flavell (1979) states, monitoring is only likely to occur in those situations ". . . where every major step you take requires planning beforehand and evaluation afterwards . . ." (p. 908).

Beliefs about the domain of problem solving may arise from certain classroom experiences. Students are often taught to look for key words in the problem that signify the need to multiply, add, and subtract. They are made aware of the surface structure of the problem rather than the deep structure. This initial problem representation may result in a correct solution; however, it may not result in a true understanding of the problem. Students can correctly solve a problem without any conceptual understanding of it (Reusser, 1988). Following mathematical procedures requires the use of cognitive strategies but may not call forth the need for metacognitive activities. Children rise to the social occasion; they ". . . grow into the intellectual life of those around them" (Vygotsky, 1978, p. 88). If problem solutions are taught on the board as simple algorithmic functions, then students will not recognize the need for executive level strategies.

The conjecture that socially acquired beliefs about the domain of problem solving may influence students' cognitive and metacognitive engagement raises two questions: first, can the context within which problem solving occurs stimulate metacognitive engagement?; second, are students dependent on contextual factors or can students' self-beliefs provide a self-initiated challenge? The answer to the first question will be addressed in the following section. The answer to the second question has not been well-documented by past research; however, the hypotheses of the present study have been formulated in response to this question. Students who attribute performance to strategies (over effort or unknown causes) were expected to be more likely to engage in an otherwise seemingly difficult problem. "If students did not see themselves as intentional learners with some control over their learning, they might be less willing to try to actively resolve discrepancies" (Pintrich, Marx, & Boyle, 1993, p. 189).

The Problem-Solving Context

Unfortunately, word problems that cannot be reduced to a step-by-step process are perceived by students as being beyond the control of their efforts. For instance, only when problems can be routinely solved do college students believe their efforts will improve their mathematical ability (Kloosterman & Stage, 1992). However, there are situations when students approach the problem-solving context with the eyes and mind of a scientist, i.e., when the problem is presented as a challenge, or outside the realm of what students normally expect. Kluwe (1987) found that when task demands are made more challenging children's use of regulatory strategies increases. Children, ages 4-7, were given five jigsaw puzzles to work on. The first three puzzles were designed so that pieces of the puzzle could be removed if the match was not correct (reversible condition). However, the last two puzzles were designed so that once a piece was placed on the surface, it could not be removed (irreversible condition). By examining eye fixations and problem-solving operations, it was noted that children of all ages increased their regulatory activities under the irreversible condition. Children were involved in more monitoring of solution processes when the risk of failure was increased.

Although this study suggests that increasing the challenge of the problem improves the level of strategy used, it does not demonstrate that the use of strategies subsequently improves performance. Reusser (1988) examined the effects of task difficulty manipulation on students' success at solving a word problem. The difficulty level of the task was manipulated in two ways: by changing the problem's wording or text (simple and complicated) and by inducing challenge through the instructions given to the subjects (induced high and low). In actuality, the problem was moderately difficult; it led one into a "common sense" solution that was mathematically incorrect. A correct solution required an in-depth analysis of the problem.

The study expected that ninth-grade and college students who were presented with a high challenge, i.e., those told that the problem has only been solved by one-third of college entrance candidates, would have a greater frequency of correct solutions when given the simple text version. The lowest frequency was expected for those receiving the complicated version and low induced difficulty. All hypotheses were upheld. Students who expected a challenging task and then determined the solution quite easily had an unfulfilled expectation which created a metacognitive re-enactment of the problem's solution process, eventually leading to a correct solution. Conversely, students who expected, and then received, the complicated version did not experience a discrepancy. They were satisfied with their original solutions, which were more likely to be incorrect.

These studies illustrate how the problem-solving context can influence students' expectations of success and failure, in turn affecting their processing of the problem. Reusser (1988) concludes: ". . . students often do not get really challenged enough to understand what is presented to them and to evaluate it by means of their own criteria of consistency and comprehension quality" (p. 324). The present study requires a problem-solving context that will maximize students' metacognitive engagement, i.e., a challenging nonroutine word problem.

Furthermore, the present study requires an assessment procedure of metacognition that differs from the above studies. In Kluwe's study regulation was defined as behavioral activities that occurred during the solution process, such as holding a selected piece close to the adhesive surface without actually attaching it. Measuring behaviors is possible in studies where the problem-solving exercise involves motoric action. The study of metacognitive "thought" must utilize alternative measures. Reusser, for instance, analyzed the written protocols of students. Another possibility, mentioned earlier, is the use of verbal protocols. Protocol analysis may be advantageous when the conditions require covert thought processes.

The second question can now be raised: Are students dependent on an environmentally induced challenge or can students' self-beliefs provide a self-initiated challenge? While the problem-solving context is deemed important, students' attributional beliefs may also determine their level of metacognitive engagement and therefore their problem-solving performance. More specifically, students who attribute performance to strategies are expected to become more metacognitively engaged during problem solving and be more likely to solve a word problem than those who attribute performance to effort or unknown causes. A preliminary step in examining this interrelated set of associations requires first the establishment of the three separate relationships: 1) metacognition and problem solving, 2) attributions and problem solving, and 3) metacognition and attributions.

Metacognition and Problem Solving

Lin, Green, and Lehman (1993) tested the effects of metacognitive training on problem-solving performance in science. College students conducted laboratory experiments testing the effects of light and moisture on isopod behavior. The problems were presented in a hypermedia environment. Metacognitive cues installed in the program were anticipated to facilitate problem-solving performance on a transfer task. The metacognitive cues were in question format and asked students to plan ahead, monitor the process, evaluate the results, and regulate accordingly. Two other groups responded to cognitive or affective questions.

Only the metacognitive group showed gains in pre-post test scores on both near and far transfer tasks, and had significantly better post-test scores than the cognitive, affective, or control groups. Interviews were conducted to learn how the students responded to the cues and if the cues influenced their task designs during training. Qualitative analyses indicated that 79% of the responses for the metacognitive subjects fell into one of five categories:

planning, monitoring, subgoaling, evaluating, and modifying (also known as regulating). Thus, the students did respond to the cues and, as shown on the transfer task when cues were no longer available, they had internalized the metacognitive prompts. This study shows that metacognitive skills do improve problem-solving performance in science. Similar relationships are found in mathematical problem solving through the use of protocol analysis.

Schoenfeld (1985) analyzed the verbal protocols of students attempting to calculate the area of an equilateral triangle. The protocols were categorized into seven problem-solving activities: reading, understanding, analyzing, exploring, planning, implementing, and verifying. As seen in Appendix A, the time spent on various activities differs drastically between novice and expert problem solvers. Typically students may spend one or two minutes reading a problem, and 15-20 exploring the solution, without any time given to analyzing, planning, or verifying the situation. Speaking of a mathematician, Schoenfeld (1992) writes: "By monitoring his solution with care- pursuing interesting leads and abandoning paths that didn't seem to bear fruit- he managed to solve the problem . . ." (p. 358).

A study by Hegarty, Mayer, and Monk (1995) looked at differences between successful and unsuccessful problem solvers based on their initial problem representations. Undergraduates worked on a series of arithmetic word problems that included relational terms, such as less than, which were either consistent or inconsistent with the operation to be performed. They found that unsuccessful problem solvers select and focus on the numbers and keywords of a problem whereas successful problem solvers build a semantic representation of the problem which may include numbers and keywords but is not limited to them. Thus, successful problem solvers make fewer translation errors and look back at the problem less than unsuccessful problem solvers; when they do reread the problem they focus on variable names more than numbers. Without a complete mental model of the problem, monitoring efforts will be focused on the surface structure of the problem.

Research has also documented that these metacognitive behaviors are predictive of problem-solving performance. Artzt and Armour-Thomas (1992) analyzed the verbal protocols of seventh-graders working on a problem in a small group setting. Metacognition was coded according to Schoenfeld's scheme with several modifications. First, a category, Watch and Listen, was added to account for activities that occur in a group setting. Second, the category 'Understanding' was separated from the category 'Reading.' Third, each category was further classified into cognitive and metacognitive episodes (Appendix B). For instance, exploration is considered metacognitive when the subject is monitoring that exploration rather than making unchecked guesses. The researchers found that, on average, 38.7% of the groups' behavior could be classified as metacognitive. Interestingly, the only group that did not solve the problem was the same group that had the lowest percentage of metacognitive behavior, 26.3% (the percentages of metacognitive behaviors for the groups ranged from 26.3% to 51.6%).

The use of metacognitive strategies predicts how well students do on problems. However, not all students employ such strategies. Fortunately, students can be taught to use strategies, as Lin et al.'s (1993) study showed, though the effectiveness of strategy training may depend on the types of strategies taught. A second study (Higgins, 1993) did not find metacognitive training to be effective. Sixth and seventh graders were trained in the problem-solving techniques: guess and check, look for a pattern, make a systematic list, make a drawing or model, and eliminate possibilities. Half of the students did not receive this training. While the trained students placed less emphasis on the role of memorization, believed that problems were solvable without reliance on external supports, and believed that mathematics was useful, there were no differences in the use of strategies between the students trained and those not trained. The authors attributed this result to the fact that students already used many of these heuristics.

Another possibility is that heuristics, such as, making a chart, are not effective for solving all problems. Furthermore, the strategies emphasized are cognitive, not metacognitive. They focus on making cognitive progress, not monitoring cognitive progress. Lin et al.'s study, which attended to the latter, had much greater success. Students need to know specific cognitive strategies, but they also need to learn how to evaluate and regulate their strategy use. In fact, Schiefele and Wild (1994) found that metacognitive strategy use (planning, evaluation, and regulation) was significantly related to course exam scores for German college students while cognitive strategy use (elaboration, organization, and rehearsal) was not.

While metacognitive strategy use is important to mathematical problem solving, students also bring to the problem-solving context beliefs and expectations about themselves as mathematicians. The personal, affective side of learning is more closely tied to academic outcomes in mathematics than in other subjects (McLeod, 1991). Furthermore, McLeod writes: "Perhaps the most productive research area in recent years has been the study of causal attributions . . ." (1991, p. 59).

Attributions and Problem Solving

As reviewed in Chapter Two, attributions are related to reading achievement (Butkowsky & Willows, 1980; Carr, Borkowski, & Maxwell, 1991; Wagner, et. al., 1989), recall performance (Fabricius & Hagen, 1984), math achievement (Bethea, 1986), visual discrimination (Diener & Dweck, 1978), persuasion ability (Anderson & Jennings, 1980), and can be re-trained to affect memory and reading performance (Borkowski, Weyhing, & Turner, 1986; Kurtz & Borkowski, 1984; Kurtz, 1989). In mathematical problem solving, this author conducted an exploratory analysis that was nested in a larger research effort of the Mathematics Assessment Project.* The findings support the need for a closer examination into the relationship between causal attributions and mathematical problem-solving performance.

Fifty-four students' paper and pencil versions of the <u>Mathematics Assessment Questionnaire</u> (MAQ) were randomly pulled from two storage cabinets holding a total of 1,358 surveys. The MAQ (Tittle & Hecht, 1990) focuses on metacognition, self-regulation, and beliefs, including attributions. The section on attributions includes twelve questions, three for each of four attribution categories (Internal, stable, controllable, ISC; Internal, stable, uncontrollable, ISU; External, stable, uncontrollable, ESU; Unknown control, UK). (Reliability estimates were established on the full sample of 1,358 students. The

* The Mathematics Assessment Project, the Center for Advanced Study in Education, Graduate Center of the City University of New York.

coefficient alphas for ISC, ISU, ESU, and UK were, respectively .62, .593, .418, and .683). The 54 students were 54% male and 46% female; 9% Asian, 33% Black, 13% Hispanic, and 41% Caucasian; and 24% 7th graders, 67% 8th graders, and 9% 9th graders. The students came from seven different urban public schools in the New York City area.

Attribution questions read, for example: When I correctly answer a question my teacher asks about word problems, I usually do not know why I get it right (UK); If I correctly answer a question my teacher asks about word problems, it is because I have the ability to learn math (ISU); If I understand the word problems my teacher does on the board, it is because I have a good teacher (ESU); and The next time my math teacher explains a word problem to the class, I expect to understand because I always listen carefully (ISC). Students respond on a 5-point Likert scale ranging from 1, very true to 5, not at all true. All statements are scored as if positively worded, thus a low score indicates an endorsement of that particular attribute.

Based on the sample's median score (65) on the math subtest of the Metropolitan Achievement Test (MAT), students were divided into low and high scoring groups. T-tests were used to examine group differences (see Table 1). There were no significant differences between the low and high group on the ISC, ISU, or ESU attributions. However, there was a significant difference for those endorsing unknown

Table 1

Mean, Standard Deviation, t-value, and Probability of Differences between Low and High Math Achievers' Responses to Attribution Statements

Attribution	Mean	SD	t-value	Probability
UNKNOWN				
Group 1	3.9048	.901	-2.13	.038*
Group 2	4.3750	.702		
ISU				
Group 1	2.8030	.827	.18	.859
Group 2	2.7604	.865		
ESU				
Group 1	3.4091	.942	-.46	.649
Group 2	3.5208	.838		
ISC				
Group 1	2.4333	.852	1.17	.247
Group 2	2.1563	.816		

Note. Responses range from 1, very true to 5, not at all true.

Group 1= MAT scores below 65.
Group 2= MAT scores above 65.

* significant at .05 level, degrees of freedom = 51.

attributions. Higher achieving math students were less likely to attribute success at problem solving to unknown causes than math students whose MAT score was below the median.

This was a preliminary effort at examining the relationship between attributions and mathematical problem solving performance and the results must be interpreted with care due to the small sample size and limited generalizability. However, the significance of unknown control has been established elsewhere. Skinner, Chapman, and Baltes (1988), using a questionnaire, found that among attributions to effort, ability, luck, powerful others, and unknown, the latter is marked by a separate factor. Effort and ability statements comprised factor I; ability (failure), powerful others, and luck marked factor II; and unknown causality stood by itself in factor III. Connell's research (1985) also demonstrates the significance of unknown control. Using the Multidimensional Measure of Children's Perceptions of Control, unknown attributions were significantly related to standardized achievement scores and had a stronger relation to such scores than did Internal control. Unknown control also significantly predicted cognitive perceived competence, mastery motivation, and autonomous judgment, over Internal control or Powerful Others control.

Unknown control may represent a vagueness about the causes of learning and performance. In math, this vagueness has been tied to achievement, negatively. Peterson, Swing, Braverman and Buss (1982) were concerned with how cognitive and attitudinal processes affect achievement in math. Second graders were videotaped as they worked a curriculum unit on probabilities in class. After they completed the unit, they watched themselves on the video and were asked to recall what they were thinking during marked episodes. Behaviors and cognitions were coded into five categories: attending, understanding, reasons for not understanding, cognitive strategies, and teaching processes. Although not discussed by the authors as an attribution indicator, the category, reasons for not understanding, directly addresses students' beliefs about the causes of outcomes. They found that "students who did not provide detailed explanations of what/why they had trouble understanding tended to do poorly on . . . the achievement test" (p. 543).

Unknown control may represent cognitive and emotional passivity resulting from long-lasting negative experiences, similar to that of "learned helplessness" (Diener & Dweck, 1978). Connell (1985) states: ". . . unknown perceptions of control appear to be the most central control dimension in a nomological net of self-related cognitions and affects and achievement within the academic domain . . ." (p. 1035). At the other extreme may lie strategy attributions. That is, strategy attributions are expected to be positively related to metacognitive strategy use and performance over attributions to effort or unknown causes.

Metacognition and Attributions

As already reviewed, the relationship between cognitive monitoring and attributions has been established in the areas of reading and memory, though the focus has been on ability, effort, luck and task difficulty. Theoretical premises indicate that the relationship between attributions and metacognition should be consistent across domains, especially when unknown and strategy attributions are considered. For instance, Flavell (1987) suggests that the development of self as a causal agent, one with "internal locus of cognitive control," may promote the onset of metacognitive processes; and McLeod (1991) states, "beliefs about self are closely related to notions of metacognition and self-awareness" (p. 64).

In a pilot study that led to the present investigation, the author hypothesized that high school students who attributed successful problem solving to unknown control or who did not attribute performance to internal controllable factors would not engage in as many higher-level metacognitive activities during problem solving as students who did attribute their success in problem solving to internal controllable factors (Fusco, 1994). Three subjects were chosen for this study from two mathematics classrooms in a Queens public high school based on their attribution responses to the Mathematics Assessment Questionnaire, computer version (MAQ-CV). While the MAQ includes various affective and motivational constructs in each of three classroom activity settings (During Class, With Others, and Homework), only responses to statements for unknown control (UK) and internal stable controllable (ISC) attributions in the During Class setting were used (see Appendix C). The Need and Strength indicators on the teachers' program for the MAQ were used to select students. Indicators highlight students that have answered two or three statements in a way that may indicate a need or a strength in that area. Three subjects were selected- two female 12th graders (one exhibiting a need in unknown control, -UK, the other exhibiting a strength in internal stable controllable attributions, +ISC), and one male 11th grader, (exhibiting a need in internal stable controllable attributions, -ISC). All subjects were in a general, non-Regents 10th grade mathematics classroom and had similar mathematical ability.

The three students were given the Banker problem, used by Artzt and Armour-Thomas (1992) in their study of seventh-grade students' cognitive and metacognitive activities in group settings. Since this problem was appropriately challenging for seventh-graders working in groups, it seemed likely that older students working individually would also find this problem challenging. A challenging problem is necessary in order for higher-order processes to be elicited (Flavell, 1979). As each student worked the problem, he or she was asked to talk-aloud and verbalizations were audiotaped. Metacognitive processes were identified and categorized into seven cognitive and metacognitive activities- read, understand, analyze, explore, plan, implement, and verify (Artzt and Armour-Thomas, 1992; Schoenfeld, 1985). Comparisons of metacognitive episodes were made for the three students. All analyses were descriptive.

During the problem-solving procedure, attributions were elicited if a comment regarding progress was made. At the solution of the problem, students were asked to respond to the question, "Why do you think you didn't get it?," in order to obtain an attribution regarding failure (Note- none of three subjects solved the problem). This open-ended format is advantageous because it does not restrict the subject's response to any particular cause.

Although there were only three subjects, differences and similarities in metacognitive processes were evident, as shown in Figure 1. All three students began by reading, understanding, and analyzing the problem. The analyses of subjects 2 and 3 led them to reduce the problem. Student 1 never reached this level of understanding. Following understanding and/or analyzing, all students proceeded to

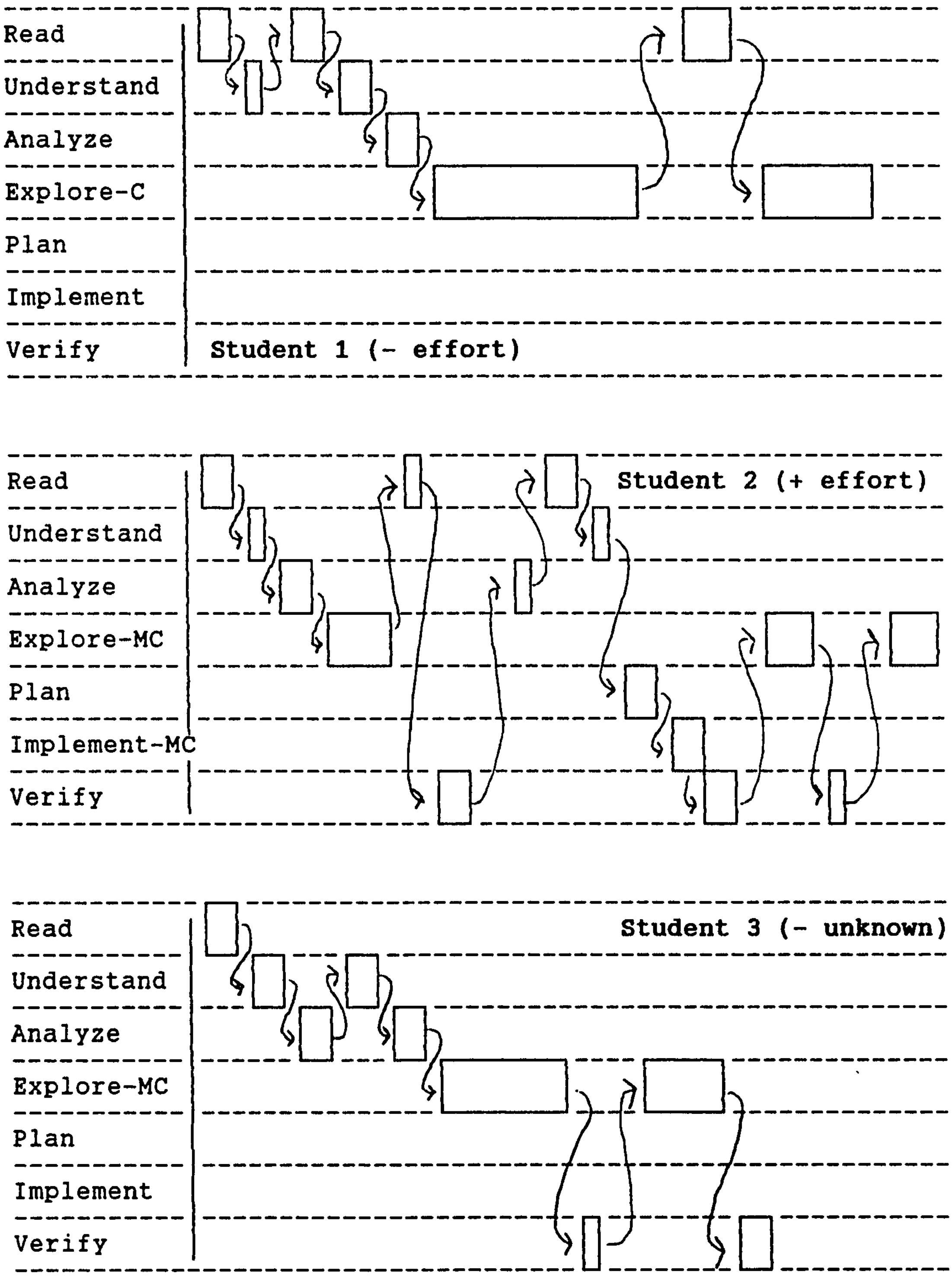


Figure 1. Sample patterns of students' metacognitive episodes. (C= cognitive; MC= metacognitive)

explore the problem solution; however, this exploration differed among the three students. Student 1's exploration was unmonitored; he was involved in a series of random, untracked trial and error attempts. Student 3's solution process involved a greater degree of metacognitive activity since she monitored her exploration and alternated between exploring and verifying. Student 2's pattern showed the greatest degree of metacognitive activity; she not only monitored her exploration but after verifying an unsuccessful solution re-analyzed the problem and devised a new plan. She regulated her cognitive activity. Metacognitive research has demonstrated that ability differences in comprehension monitoring are not found for evaluation (keeping track of cognitive progress) but for regulation (fixing cognitive breakdown) (Jacobs & Paris, 1987; Zabrucky & Ratner, 1989).

Regulation is an important aspect of mathematical problem solving. Koedinger and Tabachneck (1994) found that among twelve undergraduates solving four nonroutine math word problems, 42% of the correct solutions were the result of switching strategies at an impasse. Out of the nineteen solution attempts that involved switching strategies, fifteen, or 79%, resulted in a correct solution.

While student 3 did regulate her problem-solving solution process by switching strategies, this did not produce a successful outcome. The hypothesis regarding the inter-relationship between attributions, metacognition and problem-solving performance was not supported since none of the three students solved the problem. However, in retrospect, it is not surprising that the student who ascribed to effort as the primary cause for her success did not solve the problem. As discussed earlier, ascribing to effort to account for <u>success</u> may denote low math efficacy. This was supported by a comment the student made during the talk-aloud: "Yeah, I'm still bad at word problems. I shouldn't take this long for my age, my level, my grade. I shouldn't take this long."

<u>Procedural Issues.</u>

While the results of the pilot study have been interpreted above on the basis of theoretical grounds, there are also several procedural issues that should be considered. First, it is possible that the students' metacognition was being supported by the interviewer. For instance, at one point student 2 was exploring but not monitoring her exploration. The interviewer then asked a question that prompted the student to reread the problem and begin monitoring. Whether the student would have continued in an unmonitored exploration had the interviewer not intervened is impossible to judge. The present investigation considered the confounding nature of interaction with the interviewer, and used a different procedure.

Another potential confound is the procedure of talking aloud. The think-aloud procedure was used because, as Schoenfeld (1992) argues, protocols are appropriate for documenting the presence or absence of executive decisions in problem solving, and for demonstrating the consequences of such decisions. Furthermore, "a think-aloud protocol provides a rich basis for studying metacognition by yielding information about the subjects' task-specific cognitions, general non-task specific problem-solving strategies, as well as any affectively tied inhibitory or facilitative ideation that interrupts, interferes with, or enhances task performance" (Meichenbaum, Burland, Gruson, & Cameron, 1985, p. 23). While some have argued that the very act of talking aloud may interfere with cognitive processing, the research does not support this claim. Ericsson and Simon (1984 cited in Norris, 1990) concluded that thinking aloud does not change the course of thinking because subjects are verbalizing information that would normally be available in their short-term memory. Retrieval of information from short-term memory results in little distortion of information. Conversely, directive probes, or requests for elaboration, are likely to alter cognitive processing because the information would have to be retrieved from long-term memory or generated by inference, which is less dependable than short-term memory retrieval. The implication is that on-line verbal reports, as yielded through think aloud procedures, are accurate as long as the subject is only reporting what is available in his/her stream of consciousness.

Norris (1990) examined the validity of this theory in a testing context. The study is of particular interest since high school students comprised the sample. The sample included all tenth, eleventh and twelfth graders (n=342) from four schools in a rural area of Canada. Participants were randomly assigned to one of five groups- a control group or one of four verbal elicitation groups. The four methods of verbal elicitation, in increasing order of reliance on long-term memory, were the think aloud, immediate recall, criteria probe, and principle probe.

The students were given a 28 item multiple-choice critical thinking test, The Test on Appraising Observations. This test assesses the ability to judge the reliability of observation reports, e.g., eyewitness testimonies. As students worked on items one through fifteen, verbal reports were audiotaped. The remaining items were worked on privately. The control group worked on the entire test privately. Students received three sets of scores. The concurrent performance score was given for items 1-15; the subsequent performance score was given for item 16-28; and a thinking score was based on the quality of thinking in verbal reporting, independent of answers from the test.

The authors concluded that, ". . . the elicitation of verbal reports of thinking did not alter subjects' performance and, by inference, did not alter their thinking; and the different procedures for eliciting verbal reports yielded essentially the same information on the quality of subjects' thinking" (p. 47). Furthermore, the correlation between the quality of thinking scores and the concurrent performance scores was significant ($r = .50$, $p < .001$). These results provide validity-related evidence for the method of thinking-aloud as a potential means of assessing critical thinking. A second finding of interest was derived from a qualitative analysis of students' thinking that was based on the verbal reports. The authors discovered seven reasoning acts that occurred throughout verbal reporting: citing factual details, self-questioning, making evaluations, constructing supporting assumptions, controlling attention, interacting with the experimenter, and pausing. These reasoning acts were analyzed for general trends among the four elicitation groups. They found that "the order of magnitude of the frequency and relative proportion for each reasoning act is the same for each elicitation group" (p. 51).

In short, the use of various methods of verbal reporting did not appear to have an effect on critical thinking performance, nor on the proportions of reasoning acts. To reiterate, the most relevant finding here is that the think aloud procedure did not interfere with these high school students' ability to think critically. Though the other procedures involving recall and/or requests for reasons also did not alter thinking, the authors conclude, ". . . given that the results of this study suggest that such requests deliver nothing beyond a request to think aloud, the latter approach might be preferred" (p. 52).

In the present study, the think-aloud method was utilized and students' problem-solving processes were verified with a videotaped recording of the subjects' written protocols. This procedure provided a time-line representation of the problem-solving process and allowed for a comparison between the verbal and written data, thus increasing the reliability of coding. Furthermore, the guidelines for using concurrent verbal report data, provided by Taylor and Dionne (1994), were considered. They are: 1) instructions that emphasize the general reporting of thinking rather than justification, 2) use of warm-up exercises, 3) probes that avoid prompting, such as "Keep talking" rather than "What are you thinking?," 4) novel and moderately difficult tasks, 5) data analysis involving verbatim transcriptions, a coding grid based on the data and on theory, and established reliability of the coding, and 6) an interpretation that considers that "the knowledge accessed can be taken as positive evidence of specific forms of strategy knowledge, but a non-report cannot be taken as evidence that the problem solver does not possess that knowledge" (p. 33).

In addition to the potential confounding effects of interaction with the interviewer and the think-aloud procedure, the final methodological issue that the pilot study raised was the attribution measure. Since the interest of the present study is attributions to strategy use, effort, and unknown causes, a measure is needed that includes these categories and is specific to the domain of interest. However, both criteria could not be met with any of the measures that currently exist (see Table 2 for a summary of existing attribution measures).

Since Weiner's model has been the impetus of much attribution research, measures have focused on ability, effort, luck and task difficulty as reasons given for success or failure. The relative weight given to one reason over another is typically assessed through a forced-choice arrangement. Very little research has addressed the role of strategy or unknown attributions. Furthermore, the content of the items varies depending on the focus of the research. For instance, Goetz and Palmer (1984) designed items to reflect attributions regarding reading performance, and Kurtz and Borkowski (1984) were interested in the domain of memory. Conversely, Ames and Archer (1988) assessed

Table 2

Summary of Attribution Measures

Reference/Name of measure (when applicable)			
Categories	Grade	Domain	No. of items
Sample item			
1. Ames and Archer (1988).			
effort, ability, task, luck, strategy	8-11	General	5
Used good strategies or did not use good strategies.			
2. Carr, Borkowski, & Maxwell (1991); Kurtz (1989); Kurtz & Borkowski (1984). Krause Attribution Questionnaire			
effort, ability, task, luck	1-6	Reading Memory	5-8
You remembered that the salt shaker went with the shoes. Why did this happen? Because you're lucky, you tried hard, that pair was easy or you're smart?			
3. Connell (1985). Multidimensional measure of Perceived Control			
Unknown, Internal, Powerful others	3-9	Cognitive Social Physical, General	48
If I want to do well in school, it's up to me to do it.			
4. Curtis & Graham (1991). Therapist Attribution Style Questionnaire (TASQ)			
strategy, effort, ability, external	graduate	Health	20
You call a busy surgeon to discuss a problem with a patient and he does not return your call but instead relays the message to continue treatment via his secretary. (I did not use a good way to communicate effectively in this case with this physician).			

Table 2

Summary of Attribution Measures (cont.)

5. Diener & Dweck (1978); Wagner et al. (1989).
The Intellectual Achievement Responsibility (IAR)

Internal/external, Effort/ability	5	General	34

When you do well on a test, is that more likely because you do well on exams or because you prepare well.

6. Fabricius and Hagen (1984).

strategy	1	Memory	1

What did you do that would helped you remember?

7. Fennema, Wolleat, and Pedro (1979); Kloosterman (1988).
Mathematics Attribution Scale

effort, ability, task, environment	JHS HS	Algebra Geometry	9

You got the grade you wanted for the semester in Algebra. Was this because the class was easy, you spent a lot of time each day studying Algebra, the teacher is good at explaining Algebra, or you have a talent for math?

8. Schoenfeld (1989).

effort, ability, teachers, luck, unknown	10-12	Math Problem-solving	2

When I get a good/bad grade in math: it's because I work hard, the teacher likes me, just a matter of luck, I'm always good at math, I never know how it happens.

9. Tittle & Hecht (1990).*
Mathematics Assessment Questionnaire (MAQ)

unknown, effort	JHS/HS	Math	3

I do not know why I cannot follow the word problems that my teacher works on the board.

* Three items per construct in each of three activity settings; intended for classroom teacher use.

attributions regarding general academic performance rather than a specific domain. Only two measures are specific to mathematical problem solving (Schoenfeld, 1989; Tittle & Hecht, 1990); however, neither includes strategy attributions. Consequently, an attribution measure was developed to meet the needs of the present research. The items were adapted from prior measures (Connell, 1985; Curtis & Graham, 1991; Fennema, Wolleat, & Pedro, 1979; Skinner, Chapman, & Baltes, 1988; Tittle & Hecht, 1990). The development process for the Attribution Questionnaire for Mathematical Problem Solving and the results of piloting can be found in Appendix I.

In sum, the pilot study described above suggests that attributions and metacognition are related. The student identified as attributing problem solving success to an ISC factor, or effort, engaged in higher-level metacognitive processes during problem solving than the other two students. Since none of the three students solved the problem, the inter-relationship between attributions, metacognition, and problem-solving performance was not supported. In an effort to explain this latter finding, theoretical as well as procedural issues were raised. Theoretically speaking, strategy attributions, not assessed in the pilot study, may be a more powerful predictor of metacognitive activities and problem-solving performance than effort attributions. From a methodological standpoint, interviewer interference, the reliability of the metacognitive coding system, and/or the attribution measure used to select subjects may have contributed to effects weaker than expected. Before discussing the particulars of the present study, a theoretical and empirical basis for the relationship of attributions, metacognition, and problem solving will be examined.

Metacognition, Attributions, and Problem Solving

The previous three sections have discussed the separate roles of metacognition and problem solving, attributions and problem solving, and metacognition and attributions. Fennema (1989) provides a model in which one's internal belief system, in addition to societal influences, predicts performance on cognitive tasks indirectly through "autonomous learning behaviors" (ALB's), such as persistence and independent problem solving.

Beliefs ———→ ALB's ———→ Performance

Fennema states that the model is generic in the sense that it is "useful in a variety of situations investigating diverse variables with many age groups" (p. 205). In other words, the model can be employed to test the relationship between attributions and problem-solving performance as mediated by metacognitive behavior.

Attributions → Metacognition → Performance

This line of reasoning has been studied from a Vygotskian perspective which, while using different language than that used throughout this discussion, has concepts that are parallel. Rohrkemper (1989) studied the inner speech of eighty-four students in grades three through six. Inner speech was measured through a thought-matching questionnaire administered following problem-solving tasks of low-difficulty or high-difficulty. Students were given the questionnaire and were told to circle those statements that were in accord with what they were thinking and how they were feeling.

On tasks of low-difficulty the students reported more ability and effort attribution statements than on tasks of high-difficulty. Conversely, on high-difficulty problems, the students were engaged in strategic instruction, as well as self-statements, or self-involved speech. Under both conditions, students remained task involved through strategic instruction. This descriptive account of students' verbalizations supports the need to consider strategy statements as a necessary component of problem solving.

Cullen (1981) also studied strategic verbalizations made by children during problem solving. Ninety eight-year old children, with an equal ratio of boys and girls, from three Christchurch urban schools comprised the sample. Students were assigned to four groups based on their knowledge of coping strategies, or strategies used to overcome failure, e.g., what a student does when confronted by an unknown word when reading a story. Based on coping responses, children were divided into four groups: strategy-oriented, action-oriented, anxiety-oriented, and anger-oriented. The strategy and action-oriented groups responded with active coping attempts, though the latter was characterized by non-specific effort and external help, suggesting less autonomy than strategy-oriented subjects who cited specific effort and learned skills as ways of overcoming failure. The anxiety and anger-oriented groups made less cognitive responses to failure and had more affective reactions to failure (Rohrkemper's self-involved speech). These response patterns were related to standardized achievement. From highest to lowest, the groups' rank-orderings were: strategy-oriented, anxiety-oriented, action-oriented and anger-oriented. Furthermore, spontaneous verbalizations during the puzzle-solving task showed that the strategy-oriented and the anxiety-oriented students were engaged metacognitively in the task. They used checking, monitoring and planning strategies. "It is these general metacognitive and strategic processes which make possible the conscious control of one's own activities and facilitate efficient problem-solving in a variety of situations" (Cullen, 1981, p. 65). Unfortunately, the outcome of problem solving, i.e., success or failure, was not measured so the relationship between these metacognitive activities and actual task performance cannot be assessed. Also, the procedure used for categorizing verbalizations into metacognitive activities was not guided by a priori hypotheses. Nonetheless, the findings suggest that students' awareness of the role of strategies for overcoming failure is an important predictor of achievement, persistence, and metacognitive engagement during problem solving. Most important, this study differentiates an awareness of strategies from an awareness of effort. While strategy-oriented and action-oriented students did not differ in their persistence at the puzzle, the latter group was not as effective in their puzzle-solving processes.

Pintrich, Garcia and DeGroot (1994) did determine the relationship between metacognitive strategy use and performance, though the former was measured by a self-report questionnaire. Two-hundred and fifty seventh-grade children completed two self-report questionnaires. The first assessed positive and negative self-schemas, importance of schema, and efficacy to remain/change. The second assessed cognitive and metacognitive strategy use. Self-schemas were students' perceptions of themselves as good or poor students, i.e., they received good grades and understood the material or had a hard time finishing their work and did not know the answers when called on by the teacher. Course grades in Math, Science, English and Social Studies were also collected (only math results will be discussed here). They found that students with positive self-schemas used cognitive and metacognitive strategies more than students with negative self-schemas, and had higher grades, especially in math. While students with positive self-schemas were more likely to get better grades, it seems that the desire to avoid a negative self-schema, particularly for girls, was a strong motivating force. "It appears that the avoidance anxiety that can be generated by these negative self-schemas can lead to the recruitment of SRL strategies and better performance" (p. 19). Students' belief that they could, or could not, change interacted with this effect. That is, "a negative self-schema in Math only seems to have a negative effect on Math strategy use for students who are not confident that they can change it" (p. 17).

An interesting study might examine how attributions are related to self-schemas and the activities of self-regulation. Attributing performance to effort or unknown causes may temporarily maintain motivation and persistence, but once negative self-schemas become stable, attributions to lack of ability may prevail and self-regulatory capacity may suffer.

Summary

The use of metacognitive strategies has been linked to successful performance on many academic tasks, mathematical problem solving not withstanding (Artzt & Armour-Thomas, 1992; Lin, Green, & Lehman, 1993; Schoenfeld, 1985). Unfortunately, students often do not utilize the types of metacognitive strategies that seem most related to problem-solving success (Schoenfeld, 1992). One possible reason is that the problem itself is not challenging enough to call forth the need for metacognitive action (Kluwe, 1987; Reusser, 1988). Students come to expect that focusing on keywords, particularly operational terms, such as more than or less than, will be sufficient for solving the problem (Hegarty, Mayer, & Monk, 1995). Another possible reason is that students do not feel that success in mathematics is within their control. The relationship between attributions and metacognition has been demonstrated in reading and on memory tasks. Evidence for this pattern in mathematical problem solving was suggested by a pilot study that led to the hypotheses of the present investigation. The purpose of the present study was to determine whether attributions, metacognition, and mathematical problem-solving progress could be linked together, thus bridging the separate strands of research.

The present study builds upon prior methods of research and includes several noteworthy methodological aspects.

First, protocol analysis was used to study metacognitive processes <u>during</u> problem solving. Second, protocols were measured with both an audio (think aloud) and video component. Third, the task was a challenging nonroutine word problem which limits the availability of "keywords" and thus calls forth the need for metacognitive activities. Fourth, an attribution measure was designed that included strategy, effort, and unknown control causes.

Chapter IV

Hypotheses

There were two theoretical purposes of this study: 1) to test the hypotheses about the inter-relationships between attributions, metacognition, and performance in mathematical problem solving and 2) to include unknown and strategy attributions within the attributional framework. To examine the proposed relationships, a comparative design was used. Three groups of ninth-grade female students, who differed in their attribution beliefs, were used to examine group differences in metacognitive processes and problem-solving performance. The three categories of attribution beliefs were: 1. strategy attributions; 2. effort attributions; and 3. unknown control attributions. Scores on the Attribution Questionnaire for Mathematical Problem Solving were used to identify students for the three attribution groups. A nonroutine mathematics problem and student protocols were used for the following scores: metacognition (total); metacognitive patterns (understanding, analyzing, exploring, planning/implementing, and verifying); and problem-solving progress scores. In addition, scores on a standardized test (the Cooperative High School Entrance and Placement Exam) were used to represent prior mathematical knowledge. A secondary aim of this study was to address the methodological question: will students ascribe to strategy more frequently than effort when asked to respond openly to attribution statements, at both pre and post problem solving? The hypotheses were as follows:

Attributions and metacognition

H1: High school students selected for the strategy attribution category will have higher metacognitive scores than students selected for the effort group, who will have higher metacognitive scores than students selected for the unknown attribution category.

H2: Students who ascribe to strategy will exhibit different metacognitive patterns than students who ascribe to effort or unknown causes. The former group will be more likely to monitor and regulate their exploration of the problem.

H3: Metacognitive scores will be related to post-task attributions. The higher a participant's metacognitive score the more likely they will be to give specific, strategic explanations for task performance.

Attributions and mathematical problem solving

H4: High school students selected for the strategy attribution category will have higher problem-solving progress scores than students in the effort group who will have higher problem-solving progress scores than students in the unknown attribution category.

Metacognition and mathematical problem solving

H5: There will be a positive relationship between total metacognitive scores and problem-solving progress scores, and problem-solving progress will be positively related to metacognitive exploration and verification.

Attributions, metacognition, and mathematical problem solving

H6: Metacognition and attributions will account for increased variance in problem-solving progress over prior mathematical knowledge.

Methodology

H7: An analysis of open-ended attribution responses will reveal a higher frequency of strategy causation than effort causation for success and failure in mathematical problem solving.

Chapter V

Method

Participants

One-hundred and thirty ninth-grade math students from one urban Catholic high school comprised the sample pool used for Phase One. (Enrollment was 143 students; 13 were absent on the day the questionnaire was administered.) All participants were girls. The students ranged in age from 13-16 (13 = 32%, 14 = 56%, 15 = 11%, 16 = 01%). Based on scale scores from the Attribution Questionnaire for Mathematical Problem Solving, 49 students were assigned to one of three attribution categories: Strategy (n = 22), Effort (n = 15), or Unknown (n = 12). Fifteen students were omitted from this selection process, and from further analyses, due to missing data (n = 12) and possible biased response patterns (n = 3). Of the 49 students selected, thirty students returned parental consent forms and thus participated in Phases Two and Three of the study (ten in each of the three attribution categories: Unknown, Effort, and Strategy).

The ethnic breakdown for the thirty participants was: 40% Hispanic, 27% African-American, 10% Caucasian, 3% Asian, and 20% Other (i.e., West Indian, Brazilian, or of dual ethnic background).

Materials

The materials for this study included: two mathematical word problems (Appendix D), a parent/student consent form (Appendix E), a student agreement form (Appendix F), and video/audio equipment. The measures included: a standardized test of mathematics knowledge, the Cooperative High School Entrance and Placement Exam; the Attribution Questionnaire for Mathematical Problem Solving (Appendix G); verbal and videotaped protocols to identify metacognitive episodes and problem-solving progress (see Tables 3 and 4 for scoring schemes); a metacognitive checklist (Appendix J); and a post-task attribution questionnaire (Appendix K).

Mathematical word problems.

Two word problems were used in this study. The first, a nonroutine coin problem, was used as a practice task to familiarize students with the procedures, particularly the process of talking aloud during problem solving (as suggested by Taylor & Dionne, 1994). The second, the Banker problem, also a nonroutine word problem, was used as the primary task in order to document metacognitive activities and problem-solving progress. The Banker problem has been used with seventh-graders working in small groups (Artzt & Armour-Thomas, 1992), and by the author with individual high school and college students. The problem has proven to be challenging for high school students, a necessary requirement for the activation of metacognitive thought processes.

Prior mathematical knowledge.

To assess students' prior mathematical knowledge, standardized test scores were collected. The COOP math scores were taken from the Cooperative High School Entrance and Placement Exam administered by the Archdiocese of New York and Brooklyn. These scores are used by the school to place students into classes along the mathematics' track.

Attributions.

Attributions were measured before and after the completion of the math word problems. The Attribution Questionnaire for Mathematical Problem Solving (AQ-MPS), designed specifically for this study, was used before the problem-solving task (Phase One) in order to assign students to the three attribution categories. Items on each subscale are classified in Appendix H. The questionnaire's content validity and readability were judged by nine experts in the field of educational psychology, and the reliability was examined during pilot testing (Appendix I).

The 24-item questionnaire assesses attributions to strategy, effort, and unknown causes specific to success and failure at solving mathematical word problems. The questionnaire utilizes a 5-point Likert scale (1, very true to 5, not at all true), thus low scores indicate endorsement of the statement. There are six items for each of the Effort and Strategy scales (three worded for success and three for failure), and four items for the Unknown scale (two success and two failure). Due to high significant correlations between the success and failure subscales, evident during pilot testing, these subscales were collapsed to form three total scale scores. The range of scores for the Effort and Strategy scales is six to thirty (6 items x 1-5 response option) while the range for the Unknown scale is four to twenty (4 items x 1-5 response option).

The questionnaire also includes one item for mathematical anxiety; two items for ability attributions; three items for metacognitive strategy use; and two open-ended attribution questions (See Appendix H for scale-item breakdowns). The two open-ended items (one worded for success and one worded for failure) served to answer Hypothesis Seven, or to assess what causes students attribute problem-solving performance to when their responses are not restricted to a priori choices.

To measure attributions again after task completion, the Post-task Attribution Questionnaire was used (Phase Two). This questionnaire is an open-ended measure that asks students to explain why they think they were or were not able to solve the Banker problem. The questionnaire also contains two forced-choice items to assess students' beliefs about the most and least important causes for mathematical problem solving among the possibilities of strategy, effort, or math ability.

Metacognition.

Metacognition was assessed in Phases One and Two. In Phase One, the three metacognitive items from the AQ-MPS were used. These items reflect the metacognitive processes of evaluating and regulating cognitive activity, in this case, mathematical problem solving. Responses between the metacognitive and strategy attribution items were expected to be positively related.

In Phase Two, metacognitive activities were measured during problem solving. Pilot testing suggested that the think aloud procedure, verified with a videotaped recording of the students' written protocols, provided the greatest amount of information with the least procedural confounds. The videotape provides a visual time-line representation of the problem-solving process, and adds to the verbal and written protocols. Converging evidence of the on-line assessments increases the reliability as well as validity of the overall assessment procedure (Meichenbaum, Burland, Gruson, & Cameron, 1985).

The specific problem-solving activities measured were understanding, analyzing, exploring, planning/implementing, and verifying. These activities may either be cognitive or metacognitive depending on the level of monitoring (Appendix B). The five activities were scored separately and combined (Table 3). The scoring scheme has adapted and modified from Artzt and Armour-Thomas (1992) and Schoenfeld (1985). The separate scores ranged from 0-5, and the total score ranged from 0-25. Inter-rater reliability of the scoring scheme was examined. Two raters scored five randomly selected protocols. The consistency of ratings was 89%; after discussion the two raters met with 100% agreement.

Several aspects of the metacognitive scoring scheme are worth highlighting. First, a theoretical distinction was made between an Exploration score of five and any score less than five. A student who only makes guesses at a solution is engaged in a cognitive activity (score 1-2) whereas a student who guesses and then evaluates her guesses in relation to the problem is involved in some metacognitive activity (score of 3-4). However, only if a student utilizes the results of her evaluations, e.g., "I only used 20 coins but have one dollar (evaluation), I better increase the pennies" (regulation), would they receive a score of five. Since it was assumed that a student who did not regulate would be unlikely to solve the problem, some hypotheses were based on a dichotomous scoring of exploration (0 = no regulation, 1 = regulation).

Table 3

Scoring for Metacognitive Activities *

Cognitive Understanding (0-5 points): 1 point for each of 3 conditions; 2 points for recognizing the overall goal of the problem.

Metacognitive Understanding was defined as a verbal recounting of the problem's conditions and goal. 1 point for each of the 3 conditions; 2 points for verbalizing the goal.

CONDITIONS:
1. A total of 50 coins must be used.
2. The value of the 50 coins must equal $1.00.
3. At least one quarter, one dime, one nickel, and one penny must be used.

GOAL: *How many of each coin must the banker use to do this?*

Analyzing (0-5 points): Quality of analysis can be determined by considering the following questions: Which strategy is chosen? Is the choice made explicitly? Is the choice reasonable, driven by the conditions of the problem?

Planning/implementing (0-5 points)
1 point: Does the student show any evidence of being aware of his/her approach to the problem?

3 points: Does the student pursue the approach? (evidence plus pursuit)

5 points: Does the student monitor effectiveness of approach or does approach lead to a dead-end without the student's awareness? (evidence plus pursuit plus monitoring)

Metacognitive Exploration (0-5 points): 0 points for guessing without testing; 3 points for guessing and testing; 5 points for making new guesses based on the results of the tests.

Verifying (0-5 points): Based on verification of the three conditions above. 1 point: verifies one stipulation; 3 points: verifies two stipulations; 5 points: verifies all three stipulations.

* see Appendix B for elaborative definitions of episodes

Second, a full 25 points is not necessary in order to solve the problem. Based on prior experience with junior high school, high school, and college students solving this problem, it is possible that a score of 15 points, if the points are awarded for necessary components, could coincide with a problem solution. For instance, a student who receives 5 points in Cognitive Understanding, 5 points in Metacognitive Exploration, and 5 points in Verifying is likely to have solved the problem (see Figure 2). Analysis and Planning, though considered strategies used by expert problem solvers (Schoenfeld, 1985), are not necessary for problem solution.

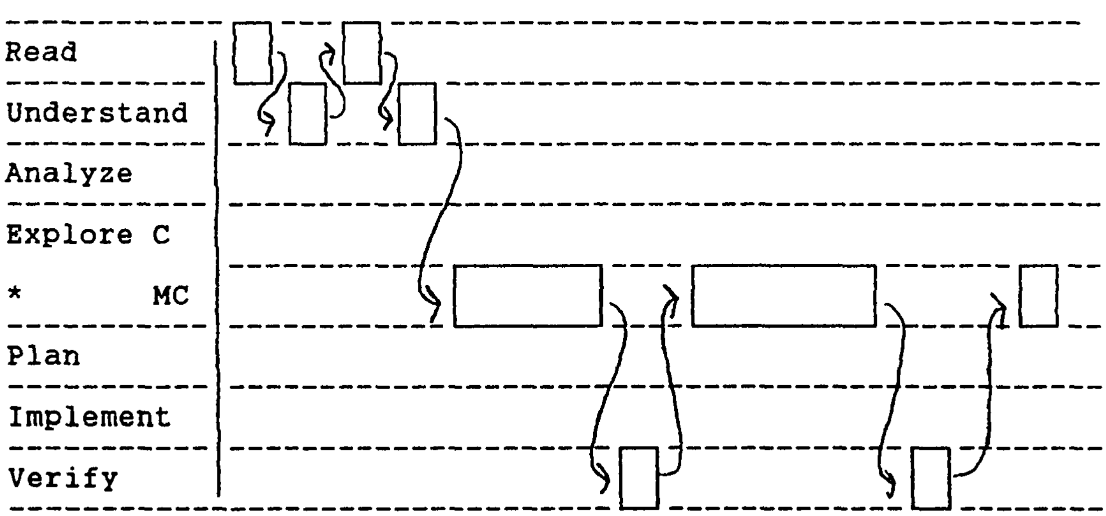


Figure 2. Exemplar of student who solved Banker problem.

* C: Cognitive; MC: Metacognitive

Third, while verification involves cognitive activities, such as adding, this episode was scored as solely a metacognitive activity. By definition, verification involves checking one's cognitive progress.

In addition to a quantitative scoring scheme for metacognition, visual patterns of the metacognitive process were of interest. Metacognitive patterns graphically illustrate at least two decision points during problem solving that are of particular interest. First, after obtaining a solution or partial solution, students may or may not verify their answer. Verification is particularly important for those students who have not monitored their exploration. In the present study, students who monitored their exploration and verified their problem solution were expected to be more likely to solve the problem than those who did not engage in these activities. The second decision occurs after students have verified their solution as incorrect (evaluation). At this point, students may either give up or return to a prior activity, such as rereading the problem (regulation). The metacognitive checklist (Appendix J) was used to document the occurrence and pattern of metacognitive activities.

Problem-solving progress.

Problem-solving performance was defined as an indication of progress with scores ranging from 1 (little progress) to 5 (solved). A progress score has advantages over a dichotomous scoring system in that it defines problem solving as a process rather than all-or-none performance. The scoring scheme was adapted from Schoenfeld (1982) and is appropriate for use with high school students (Table 4).

Table 4

Scoring for Problem-Solving Progress

Progress	Points	Definition
Little	1	Much guessing but no clear understanding of problem
Some	2	A reasonable amount but not enough to claim the solution is almost in hand
Almost	3	Something close to a solution
Solved, with error	4	Correct solution marred by an incorrect calculation
Solved	5	Correct solution: 45 pennies .45 2 nickels .10 2 dimes .20 1 quarter .25 ------------ ----- 50 coins = 1.00

Adopted from:

Schoenfeld, A. (1982). Measures of problem-solving performance and of problem-solving instruction. Journal for Research in Mathematics Education, 13, 31-49.

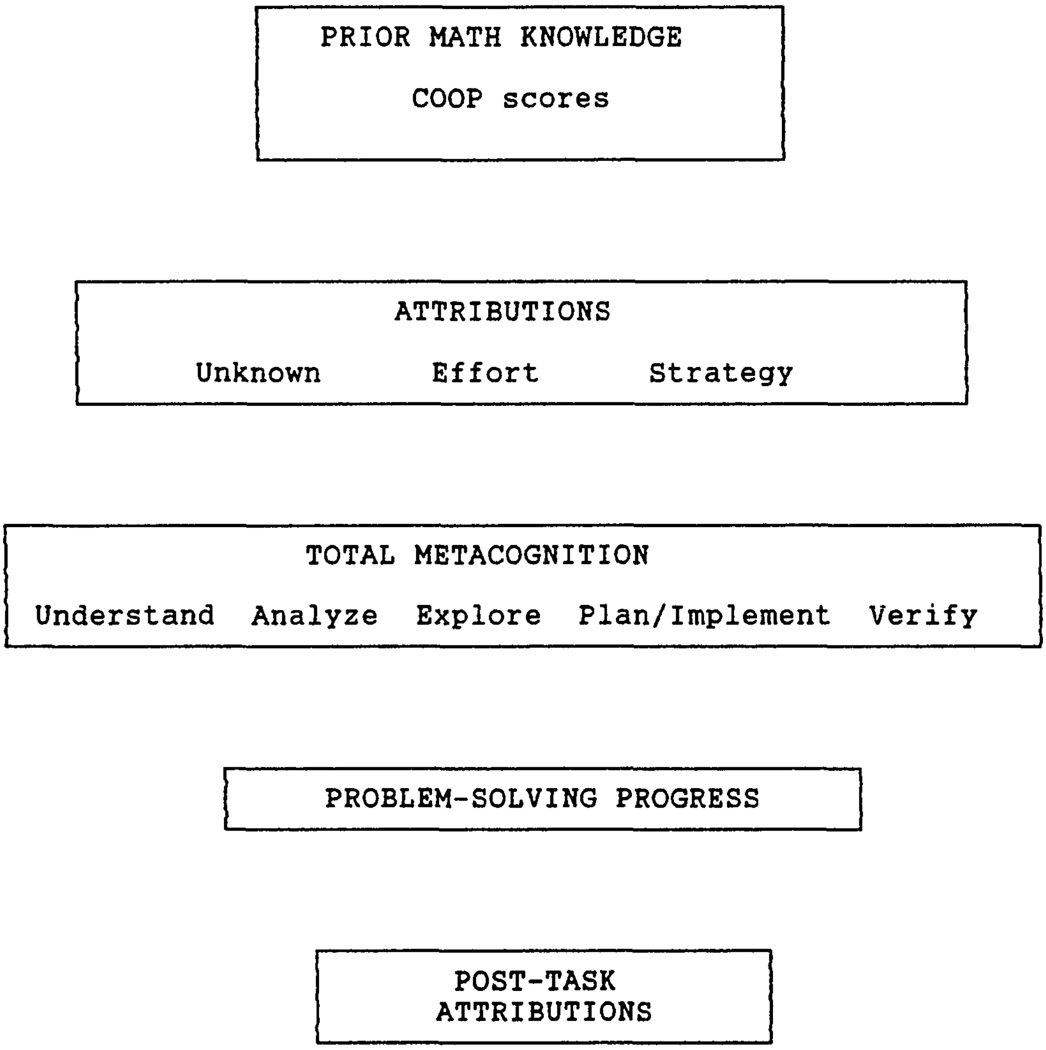


Figure 3. Summary of variables under investigation.

Procedure

There were three phases to this study. Phase One was based on the 130 female students who completed the Attribution Questionnaire for Mathematical Problem Solving. The data collected in this phase was used to test Hypothesis Seven. Phase Two consisted of thirty students who were identified as attributing performance in mathematical problem solving to strategy, effort, or unknown causes (ten students for each attribution category). These thirty students were drawn from the 49 students who met the attribution selection criteria (see Figure 4) and on the basis of parental consent. The data from Phase Two was used to test all hypotheses except for seven and three. Phase Three consisted of fifteen students who incorrectly declared they had solved the problem (before the allotted time) and made a second attempt with some level of prompting. Since the post-task attribution questionnaire was administered at the end of the allotted time (twenty minutes), regardless of whether or not students made a second attempt of the problem, Hypothesis Three is discussed in the Phase Three section.

In Phase One of the study, the Attribution Questionnaire for Mathematical Problem Solving was group-administered by two female math teachers to 130 ninth-grade students from six math classrooms. Each student received three total attribution scores, one for each category-

Unknown, Effort, and Strategy. Ten students were selected for each of the three categories based on the criteria shown below in Figure 4. (A low score, i.e., one through three, on a 5-point rating scale, indicated endorsement of the attribution item.) Five students selected for the Strategy category also had low Effort scores, that is, attributed performance to effort. It was expected that the recognition of strategy as causal to performance independent from, or in addition to, effort would be more strongly related to metacognitive activities than effort alone.

Category	Unknown	Strategy	Effort
No.items	4 items	6 items	6 items
Range of scores	4 - 20	6 - 20	6 - 20
Selection criteria	= or < 13	= or < 12	= or < 12
	and greater than 12 on Strategy and Effort	and greater than 12 on Unknown	and greater than 12 on Strategy and Unknown
	No "4" or "5" responses		

Figure 4. Attribution scoring scheme.

Parent and student consent forms to participate in the study were handed out to all ninth-grade students so that students were not aware of the selection process.

In Phase Two of the study, the thirty selected students were seen individually on the stage of the auditorium. Privacy was maintained by keeping the stage curtains drawn. A card table and folding chairs were provided by the school principal. The participants first received the primer task, or simple coin problem, in order to become familiar with the presence of the video and audio recorders, and the process of talking aloud. The videorecorder was positioned for a side view of the student working on the problem; only the students' handwriting was captured. Participants used a thin black magic marker so that their handwriting was perceptible on the videotape. Once the student was comfortable with the procedures, she worked on the Banker problem. Instructions for each problem were written on top of the worksheet and were read aloud. Each student was given twenty minutes to work on the problem. During this time the interviewer remained at the table, but occupied herself with "busywork" to avoid the invitation for interaction. After twenty minutes or when students correctly solved the problem, the problem-solving session was deemed complete.

Phase Three was applicable for fifteen students who finished working on the problem before the elapsed time but did not achieve a correct solution. When asked to explain their approach to the problem or when given a direct prompt, students recognized their error and went into a second attempt of the problem. Fifteen students received a second set of scores for their re-attempts, which were analyzed separately (these results can be found in Appendix M).

Students completed the Post-task Attribution Questionnaire after they finished working on the problem and then signed a statement agreeing not to talk to their peers about the problem or procedure. Each student received a coupon for a free slice of pizza and soda redeemable at the local pizza parlor as a stipend for participation.

Data Analysis

The main independent variable was students' group assignment (Strategy, Effort, or Unknown). The original attribution subscale scores were also used for one analysis. The main dependent variables were metacognition, problem-solving progress, and post-task attributions. Prior mathematics knowledge was used as a background variable. Several analyses were undertaken to test the hypotheses.

Phase One.

Hypothesis Seven, *open-ended attributions to strategy would be more frequent than attributions to effort for success and failure in mathematical problem solving*, was tested first since data from the AQ-MPS was obtained in Phase One of the study. Students' responses on the open-ended items were analyzed separately for attributions following failure (item 23) and success (item 24). Statements which included more than one cause for performance were parsed and counted as separate statements. Statements were then grouped into categories based on the similarity of the responses. The percentages of responses in the strategy and effort categories were compared using a chi-square analysis.

Phase Two.

Hypotheses One and Four proposed group differences on metacognitive scores and problem-solving progress scores, respectively. To test these hypotheses, attribution category was used as the independent variable in two one-way Analysis of Variance, with total metacognitive score as a dependent variable in one analysis and problem-solving progress score as a dependent variable in the second analysis. The main effects for groups were expected to be significant for both dependent variables. Post-hoc analyses were hypothesized to show that the Strategy group would outperform the Effort group who would outperform the Unknown group on both dependent variables.

To test Hypothesis Two, *students in the Strategy group were expected to be more likely to regulate their exploration than students in the other two groups,* exploration scores were recoded dichotomously according to the criteria, scores of zero through four = zero; five =

one. A score of five indicated that students kept track of their problem-solving process and built upon the results of their evaluations. The hypothesis was tested with a chi-square analysis. An analysis of variance was also performed using Metacognitive Understanding, Cognitive Understanding, Analyzing, Exploring, Planning/Implementing, and Verifying as the dependent variables and Attribution Group as the independent variable.

Correlations were computed to test Hypothesis Five. Total metacognitive scores and problem-solving progress scores were expected to be positively correlated. Furthermore, exploration and verification were expected to be significantly related to problem solving.

Hypothesis Six, *metacognition and attributions will account for increased variance in problem-solving progress over prior mathematical knowledge*, was tested with a stepwise multiple regression analysis. The variables entered were: COOP math scores, metacognitive scores and attribution subscale scores. Problem-solving progress was used as the outcome variable. Attributions and metacognition were expected to account for greater variance than prior math alone.

Phase Three.

Hypothesis Three, *students with high metacognitive scores would respond to the Post-task Attribution*

Questionnaire with specific strategic causal explanations, was tested by coding the responses into four categories, according to whether they made reference to a specific strategy, effort, an external cause, or other cause. A one-way analysis of variance, with metacognitive scores as the dependent variable, was used to test for group differences.

In sum, seven hypotheses were tested in three phases of the research. Table 5 summarizes the data analysis procedures for each of the seven hypotheses.

Table 5

Summary of Variables under Investigation: Phase, Hypothesis Tested and Data Analysis

Phase	Hypothesis	Data Analysis	Variable(s)
ONE	7	chi-square	AQ-MPS, open-ended items
TWO	1	ANOVA	Attribution\Metacognition
	2	chi-square	Attribution\Exploration
	4	ANOVA	Attributions\Problem Solving
	5	correlation	Metacognition\Problem Solving Exploration\Problem Solving Verification\Problem Solving
	6	regression	Prior math knowledge\Problem Solving\Attributions\ Metacognition
THREE	3	ANOVA	Metacognition\Post-task Attributions

Chapter VI

Results

Phase One

Phase One consisted of 130 ninth-grade math students who completed the AQ-MPS. This section discusses the data obtained from both the open-ended and scaled items on the questionnaire. To test Hypothesis Seven, the open-ended items were analyzed for the frequency of strategy and effort attributions. The closed or scaled items were analyzed for inter-item and inter-scale relationships. Of particular interest was the relationship between the metacognitive and attribution items.

Open-ended items.

Of 126 students who responded to item 23, or "When you cannot solve a word problem why do you think this happens?", 82 gave one reason for their failure, 41 gave two reasons and three students cited three reasons. This resulted in 173 attribution responses for failure. Of 125 students who responded to item 24, or "When you can solve a word problem why do you think this happens?", 80 gave one reason, 41 gave two reasons, and four gave three reasons for success, resulting in 174 attribution responses. Responses were sorted and then grouped into twelve categories (Table 6) based on the similarity of the response.

Table 6
Categories of Open-Ended Attribution Responses

Category Sample Statement	Frequencies/percentages* Success	 Failure
Problem-Solving Strategy Because I didn't follow the right procedure	**34/.20**	**15/.09**
Comprehension of Procedure Because I knew how to get the answer	30/.17	24/.14
Error Maybe I missed a step	1/.01	9/.05
General Strategy It happens because I don't pay attention in class	16/.09	13/.08
Effort Sometimes it's because I don't try hard enough	**25/.14**	**18/.10**
Comprehension Because I understood the problem	22/.13	**34/.20**
State Because I get tired quickly	12/.07	23/.13
Affect Because it makes you feel good when you solve it	12/.07	23/.13
Task Because it's hard	17/.10	10/.06
Other The teacher didn't explain it very good	3/.02	2/.01
Ability I am good at solving problems	1/.01	2/.01
Unknown I don't know	1/.01	0/.00

Note: Sample statements reflect either success or failure.
* As percentage of all responses

To test Hypothesis Seven, *an analysis of open-ended attribution responses will reveal a higher frequency of strategy causation than effort causation for success and failure in mathematical problem solving*, the difference between two proportions (strategy and effort attributions) was examined using a chi-square analysis. To ensure independent samples, students who attributed performance to both strategy and effort were excluded, and if a student made reference to two strategies it was counted as one; thus, the proportions used in this analysis will differ from those in Table 6 above. Thirty students gave attribution responses for failure to effort or a problem-solving strategy. Seventeen students attributed performance to effort (57%) and 13 to a problem-solving strategy (43%), a significant difference (chi-square = 15.29, $df = 1$, $p < .001$). Although effort was more frequently cited than strategy, it was not the most frequent cause cited. Students believed that failure was most likely the result of a lack of problem comprehension (20%). For success, students were significantly more likely to ascribe to strategy (20%, $N=29$) than effort (14%, $N=22$) (chi-square = 24.98, $df = 1$, $p < .001$). The use of a problem-solving strategy was the most frequent cause cited for success and comprehension of procedure was the second most frequent response (17%). Hypothesis 7 was supported following success but not failure.

Closed-items.

The relationship between attributions and metacognition was examined using the AQ-MPS subscales. Only students who met the criteria shown in Figure 4 above (n = 49) were included in this analysis.[1] The main prediction, though not a hypothesis of this study, was that strategy attributions would be more strongly related to metacognition than effort attributions. This was supported for a successful outcome (see Table 7). The metacognitive scale was positively related to the Success-Strategy subscale (and the Success-Unknown subscale), but was not significantly related to the effort subscales.

To further explore this relationship, a one-way ANOVA was performed using attribution group as the independent variable. Students who endorsed both strategy and effort comprised a separate group. There was a significant difference between the groups, $F(3, 45) = 4.51$, $p = .008$. A post-hoc procedure revealed that the Strategy-effort group (M = 6.00, sd = 1.76, n = 12) was more likely to report using metacognitive strategies than the Unknown group (M = 9.08, sd = 2.87, n = 12). No other pairs were significantly different. The mean for the Effort group was 7.13 (sd = 1.60, n = 15) and for the Strategy group, 7.00 (sd = 2.05, n = 10).

1 Thirty students were used in Phases Two and Three of the study. While 49 students met the criteria, 19 were not used in later phases due to lack of parental consent.

Table 7

Correlations between Metacognitive and Attribution Subscales

Outcome Attribution	Metacognition
Success	
Effort	.3007
Strategy	.3614*
Unknown	-.4056*
Failure	
Effort	.2251
Strategy	.2659
Unknown	-.3188

* $p < .01$

By definition the Strategy-effort group reported a conviction to both strategy and effort as causal to performance. Specifically, this group attributed _success_ to both strategy and effort. This dual attribution pattern resulted in differences compared to the unknown group in Phase One. Students who attributed success to the use of a strategy and to effort were more likley to report using metacognitive strategies, such as checking their solutions, than students who attributed performance to unknown causes. However, the results of Phase Two are not the same; reasons for the contradiction will be explored in the _Discussion_ section.

Phase Two

The data collected during Phase Two were: metacognitive scores, separate and total, and problem-solving progress scores. Scores for metacognition and problem solving were based on the activities that occurred between the time students began working on the problem to the time they reported finishing the problem, or when the allotted twenty minutes had elapsed. Only ten students utilized at least eighteen to twenty minutes. Interestingly, the Effort group ascribed to the belief that working hard and persistence are causal to performance. However, on average they spent the least amount of time on the problem (M = 7.1 minutes), significantly less than the Unknown group, $F(2,27)$ = 4.578,

p =.02. Students from the Unknown group spent on average 15.4 minutes and the Strategy group spent, on average, 9 minutes solving the problem. *Less time was not the result of solving the problem*; the correlation between time and problem-solving progress was in a positive direction, r = .34, p = .03. Time was also positively related to Total Metacognition (r = .41, p = .01), Exploration (r = .51, p = .002), and Cognitive Understanding (r = .45, p = .006).

The results of testing the hypotheses are discussed below under the headings: Attributions and metacognition (H1, H2); Attributions and problem solving (H4); Metacognition and problem solving (H5); The relevance of prior mathematical knowledge (H6); and Phase Three (H3). See Table 5 (page 114) above for a summary of the variables under investigation as related to the phase of the study, hypothesis tested, and data analysis.

The inter-correlations among all of the variables in this study (prior mathematical knowledge, attribution and metacognitive subscales, problem-solving progress, total metacognition, understanding, analyzing, exploring, planning/implementing, and verifying) can be found in Appendix N.

Attributions and metacognition.

Hypothesis One asserted that *students who attributed problem-solving performance to strategy would have higher* *metacognitive scores during problem solving than students who ascribed to effort or unknown causes; and the Effort group was expected to have higher metacognitive scores than the Unknown group.* Using a one-way analysis of variance, with total metacognitive score as the dependent variable and group assignment as the independent variable, this hypothesis was not supported, $F(2, 27) = 1.12$, $p = .34$. There were no significant differences between the three groups. The respective means and standard deviations were: Strategy, $M = 6.0$ ($sd = 4.6$); Effort, $M = 4.4$ ($sd = 2.1$); Unknown, $M = 6.3$ ($sd = 1.4$). Three students in the Strategy group received the three highest metacognitive scores (10, 11, and 12); however, the variability within the group resulted in a lower average metacognitive score.

Hypothesis Two was concerned with the specific episodes of metacognitive strategies used during problem solving. The prediction was that *the Strategy group would be more likely to monitor and regulate their exploration than students from the other two groups.* Students who tested their guesses, e.g., "I used 20 coins and got one dollar", but did not build upon these results, e.g., "I can increase the number of coins used by adding more pennies," were not as metacognitively engaged as those who did regulate their attempts. In numerical terms, regulation was equivalent to a score of five in Exploration. To test Hypothesis Two, exploration scores were dichotomously recoded according to the following criteria: 0-4 = 0; 5 = 1. Four students in the Strategy group received a score of five in Exploration while none of the students from either the Effort or Unknown group received this score. A partitioning chi-square analysis confirmed a significant difference; the Strategy group was significantly different from the Effort and Unknown groups (chi-square = 15, $df = 2$, $p < .001$).

Attributions and problem solving.

Hypothesis Four stated that *the Strategy group would significantly outperform the Effort group who would outperform the Unknown group in their problem-solving progress.* A one-way analysis of variance with attribution group as the independent variable and problem-solving progress scores as the dependent variable found no significant differences, $F(2,27) = 2.59$, $p = .09$. The means and standard deviations for the three groups were: Strategy, $M = 2.7$ ($sd = 1.6$); Effort, $M = 1.5$ ($sd = .71$); Unknown, $M = 2.1$, ($sd = .99$).

Another way to look at problem solving was dichotomously (solved vs. not solved). This strict definition of problem solving was not included as part of the prediction since it seemed more informative to recognize the gradations of the problem-solving process. Only four students solved the problem (progress score of 4 or 5), three from the Strategy group and one from the Unknown group. A partitioning chi-square was used to test for differences between the Effort and Unknown groups, and the Strategy group as compared to both the Effort and Unknown groups. Neither test was significant (chi-square = .55, 3.1, respectively, $df = 1$, $p > .05$).

Correlations among attribution subscales and Phase Two outcomes.

Thus far, differences between the three groups on total metacognition and problem-solving progress were not found. The strategy group, however, was more likely to regulate their exploration. A closer look at the correlations between the Phase Two outcomes (problem-solving progress, total metacognition, and exploration) and attribution subscale scores revealed several noteworthy relationships (see Table 8). All three Phase Two outcomes were positively related to both Effort subscales indicating that *students who attributed performance to effort (low scale scores) had low scores on the outcome variables.* While not significant, the relationship between the Success-Strategy subscale and problem solving was in the predicted direction ($p = .09$), and the two best predictors of problem-solving performance, among the attribution subscales, were Success-Effort, $F(1,28) = 6.3$, $p = .018$, and Success-Strategy, $F(2,27) = 5.8$, $p = .008$, accounting for 30% of the variance in problem-solving progress (Appendix L).

Table 8

Correlations between Attribution Subscales and Phase Two Outcomes [1]

Attributions	Phase Two Outcomes		
	PS	TotMeta	Explore
Success			
Effort	.4289**	.3025*	.3071*
Strategy	-.2485	.0415	-.1610
Unknown	.0785	-.0743	-.0537
Failure			
Effort	.3561*	.3182*	.3525*
Strategy	.0993	.2209	.1351
Unknown	.0487	-.1370	-.2014

1 Attributions are scored so that a low score is a high endorsement; positive r's for effort and problem solving, for example, indicate a low frequency of effort attributions and greater success on problem solving.

* $p < .05$, ** $p < .01$

Differences based on four groups.

Given that effort attributions were inversely related to Phase Two outcomes and five students in the Strategy group also ascribed to effort, differences between the Strategy-only and the Strategy-Effort students were examined. First, means on the attribution subscales were computed for the four groups. As Table 9 shows, the Strategy-Effort group attributed success and failure to both effort and strategy.

Table 9

Attribution Subscale Means and Standard Deviations

	Subscales			
Group	Fail-Eff	Succ-Eff	Fail-Stra	Succ-Stra
Strategy	10.2	7.8	7.4	4.6
(n=5)	(2.17)	(1.30)	(1.52)	(.894)
Stra-Effort	6.8	4.8	5.6	3.6
(n=5)	(1.64)	(.837)	(.894)	(.548)
Effort	5.7	4.8	9.0	6.5
(n=10)	(1.25)	(.789)	(1.15)	(2.01)
Unknown	9.9	6.8	9.4	7.1
(n=10)	(1.73)	(2.20)	(1.90)	(1.91)

Next, a multivariate analysis of variance was performed using the four attribution group categories as the independent variable. The dependent variables were: problem-solving progress, total metacognition, and the five separate metacognitive activities. There was a significant difference on problem-solving progress, $F(3,26) = 4.510$, $p = .011$ (see Table 10). A Tukey comparison indicated that the Strategy-only group had higher problem-solving progress scores than the Effort group. In brief, it seemed that students who did attribute success to strategy and did not attribute success or failure to effort were more likely to have higher problem-solving scores. No other differences were significant.

As Table 10 shows the Total Metacognitive mean score for the Strategy-only group was high but not significantly different from the other groups. The high standard deviation seems to account for an insignificant Analysis of Variance result. For exploratory purposes, individual scores were observed. One student from the Strategy group gave up and received a score of zero on Total Metacognition. Since one student from each of the three groups gave up, these students were dropped and a second ANOVA was performed with $n = 9$ for each group. This analysis was significant, $F(3,23) = 4.09$, $p = .018$. The Strategy-only group ($M = 9.5$) had a higher total metacognitive mean score than the Strategy-Effort ($M = 4.4$) or Effort ($M = 4.6$) groups.

Table 10

Means and Standard Deviations of Problem-Solving Activities and Outcomes for each Group

	Group			
	Unknown	Effort	Stra-Only	Stra-Eff
PS Progress	2.1	1.5	3.6	1.8
	(1.24)	(.707)	(1.67)	(1.09)
TotalMeta	6.3	4.4	7.6	4.4
	(1.41)	(2.11)	(4.72)	(4.39)
Understanding	2.1	2.0	1.6	1.8
	(1.19)	(1.05)	(1.52)	(2.05)
Analyzing	.7	.2	1.2	.6
	(.948)	(.421)	(2.17)	(.894)
Exploring	2.7	1.6	4.0	2.0
	(1.49)	(1.50)	(2.24)	(1.87)
Verifying	.7	.3	.8	.0
	(1.25)	(.483)	(1.30)	(.000)
Planning	.1	.3	.0	.0
	(.316)	(.948)	(.000)	(.000)

Metacognition and problem solving.

Hypothesis Five, that *there would be a significant correlation between total metacognition and problem-solving progress scores*, was confirmed (r = .675, p < .001). As predicted, problem solving was also significantly related to Exploration (r = .731, p < .001). Unexpectedly, problem solving was not related to verification (r = .166); however, 73% of the students did not verify.

With regard to the other metacognitive episodes, Analysis (r = .434, p < .01) and Cognitive Understanding (r = .568, p < .001) were related to problem-solving progress. While Analysis was related to problem solving it was not necessary for problem-solving success. Of the two students who correctly solved the problem, one received an Analysis score of five, the only five awarded in this area, and the other scored only one point. Planning was not related to problem solving (r = .078) since only two students devised a plan by which to solve the problem (though one of these students did solve the problem in her second attempt, Phase Three). Metacognitive Understanding was also not related to problem solving (r = .047).

The relevance of prior mathematical knowledge.

Prior mathematical knowledge was measured by a standardized test, the Cooperative High School Entrance and Placement Exam. Hypothesis Six, *Metacognition and* *attributions will account for increased variance in problem-solving progress over prior mathematical knowledge*, was based on the premise that standardized tests, while serving a practical function for the school, were far removed from the realities of problem solving, and that specific cognitive and affective processes would prove more useful indicators of task performance. This hypothesis was tested using a stepwise regression analysis. Metacognitive scores, attribution scale scores, and math (COOP) scores were used as predictors of problem solving. Since there were strong correlations among the success and failure attribution subscales (Table 11) they were combined for this analysis; three scales were used: Unknown, Effort, and Strategy.

Table 11

Intercorrelations among Attribution Subscales

		Failure	
	Effort	Strategy	Unknown
Success	.5091**	.4543**	.4207*

* $p < .01$, ** $p < .001$

As Table 12 shows, the best predictor of problem solving was the Effort scale, $F(1,22) = 14.709$, $p = .0009$. The second and last predictor was Total Metacognition, $F(2,21) = 12.15$, $p = .0003$. Prior mathematical knowledge was not predictive of mathematical problem solving, $r = .16$.

Table 12

Summary of Regression Analysis for Variables Predicting Problem-Solving Progress (N = 24) [1]

	Variable	B	SE B	β	R^2
Step 1	Effort	0.20	0.05	0.63*	.40
	Math			0.21	
	Strategy			-0.13	
	Unknown			0.17	
	TotMeta			0.42*	
Step 2	Effort	0.14	0.05	0.44*	
	TotMeta	0.16	0.07	0.42*	.54
	Math			0.03	
	Strategy			-0.19	
	Unknown			0.24	

Note: The correlations between problem-solving progress and the predictors were: Effort (.6213*), TotMeta (.6330*), Math (.1609), Strategy (-.0287), Unknown (-.1476). Again, positive beta weights indicate that effort attributions are inversely related to problem-solving scores.

1 COOP scores were not available for six students.

* $p < .05$

Phase Three

When students reported that they had solved the problem, the interviewer asked each student to explain her approach. This indirect prompt lead five students to recognize that they in fact did not solve the problem; in other words, it forced them into verifying their solution. Four students only become aware that they did not solve the problem when prompted to reread, and six students needed a direct prompt to the specific aspect of their misunderstanding, e.g., that 50 coins must be used, in order to realize that they had not solved the problem correctly. Consequently, fifteen students, who incorrectly solved the problem prior to the elapsed 20 minutes made a second attempt.

Three of these students were from the Unknown group and four were from the Strategy group. Eight of the fifteen students who thought they solved the problem were from the Effort group. To compare the percentages of students across groups who thought they solved the problem with those who did not make this assertion a partitioning chi-square analysis was used. The Unknown and Strategy group did not differ (chi-square = .220, $p > .05$), however, the Effort group appeared to differ from the other two groups. Using a stringent criteria ($df = 2$) for this post-hoc observation, the chi-square did not reach significance (chi-square = 5.40, $p > .05$), though the difference was significant when the less stringent critical value (df = 1, critical value = 3.84), was used.

At the end of the problem-solving session, that is, when students either solved the problem or when twenty minutes had elapsed, the Post-Task Attribution Questionnaire was administered. The questionnaire asked students to choose which was most and least important for problem-solving performance among ability, effort and strategy, and included an open-ended question requesting a causal statement about actual task performance. The data from the open-ended question was used to test Hypothesis Three, *the higher a student's metacognitive score the more likely they will be to give specific strategic explanations for task performance.*

To test this hypothesis, attribution statements were categorized into four groups: External (n = 5), Effort (n = 1), Strategy (n = 9), and Other (n = 10). Five students were omitted since they responded as if they solved the problem when in fact they did not. An analysis of variance was used to test for group differences on overall metacognition. The Other group was excluded from this analysis, due to the limited power of small groups sizes. There were significant differences, $F(2,12) = 11.98$, p = .0014. A Tukey comparison showed that the External group had higher metacognitive scores (M = 6.2, sd = 2.05) than the Effort group (M = .00, sd = 0.00), and that the Strategy group had higher metacognitive scores ($M = 9.44$, $sd = 2.01$) than both the External and Effort groups, thus confirming Hypothesis Three.

Two limitations of this result are important to consider. First, there was only one student who attributed performance to effort. Table 13 shows sample attribution responses for each of the four categories, and includes the students' problem solving and metacognitive scores. Second, attributions to strategy, were more likely following success than following failure. Given the close relationship between problem solving success and metacognition, the results are confounded by actual task performance. Of six students who responded to a successful outcome, five attributed success to strategy (83%) (see Table 14). Of nineteen students who responded to an unsuccessful outcome, only three attributed failure to a lack of strategy (16%). This finding replicates the finding from Phase One, namely, attributions to a problem-solving strategy were more likely to occur after success (20%) than after failure (9%).

Also as found in Phase One, attributions following failure were typically more external, "Because I thought it was hard," and often referred to a lack of understanding, "I wasn't able to because I didn't understand at first why you could only use one coin but it said at least one but I still didn't get it."

Table 13

Post-task Attribution Responses

Scores		ATTRIBUTION CATEGORY
PS [1]	Meta [2]	Actual statements
		STRATEGY
4	8	I was going about it wrong and my work was a mess.
5	12	I think what helped me solve this problem was making a chart. Even though my scrap is disorganized the chart made my steps legible.
5	10	I put a lot of faith on myself. I try many different ways up to I solve the problem correctly.
		EFFORT
1	0	Because I didn't paid attention to what the problem was saying. I wasn't trying hard.
		EXTERNAL
1	3	Because I thought it was hard.
		OTHER
2	5	I wasn't able to because I didn't understand at first why you could only use one coin but it said at least one but I still didn't get it.
2	5	I was not able to solve it because I could not find out how many pennies I needed.

1= Problem Solving Progress Score
2= Metacognitive Total Score

Table 14

Attributions Following a Successful Task Outcome ($\underline{n}$ = 6)

Strategy Attributions:

". . . I started to do pictures and drawings . . "

"I think what helped me solve this problem was making a chart . . ."

"I think I was able to solve the problem because I followed the directions."

". . . I figured out a way to do it."

". . . I try many different ways up til I solve the problem correctly."

Other Attributions:

"I think I was able to solve it mostly because of skill and luck."

In addition to the data used to test Hypothesis Three, the post-task attribution questionnaire yielded several other interesting findings. First, 77% of the participants chose ability as the least important aspect of problem solving. Second, most important for problem solving were effort (47%), strategy (37%), and ability (10%). None of the students from either strategy group chose ability as most important (students who endorsed both strategy and effort were separated from those who endorsed strategy only). Among the Effort group, 60% reliably chose effort and among the Strategy-only group, 60% chose strategy as most important. Finally, of the four students who correctly solved the problem, three believed that strategy was most important. All four believed ability was least important for problem-solving performance.

CHAPTER VII

Discussion

The main intent of this investigation was to study the inter-relationship between metacognitive and attributional processes in the domain of mathematical problem solving. To the extent that the two can be separated, the results of this study become twofold. One aspect of this study addressed students' causal beliefs as relevant to the activities and outcomes of mathematical problem solving. Differences between attributions to effort, strategy, and unknown causes among ninth-grade female students were investigated in a metacognitive model of problem solving. The second aspect of this study focused on the specific relationship between the strategies students used to solve a nonroutine word problem and their problem-solving performance. In this regard successful and unsuccessful problem solvers were distinguished. Both aspects of this study have implications for future research and educational practice on their own merits and in their totality.

Before elaborating on the results of this study several limitations will be highlighted as follows: 1) the nature of nonroutine word problems, 2) generalizability across gender, and 3) the relevance of prior mathematical knowledge. Methodological limitations are also discussed throughout the remainder of this section, and in particular can be found in the subsections, Attribution Assessment and Metacognitive Assessment.

Limitations

The nature of nonroutine word problems.

A routine word problem evokes a recognition of the problem as a particular type. Often relevant information within the problem statement serves as a cue for problem-type recognition. Experienced math students may have automatic access to the knowledge necessary for problem translation and solution. In routine problem solvng, prior mathematical knowledge is a relevant predictor of problem-solving success. Conversely, nonroutine or nonstandard word problems are those typically not covered in high school courses. However, solutions to the problems do not require mathematical techniques with which students are not familiar (Schoenfeld, 1985).

In the present study, a nonroutine word problem was chosen for two reasons. First, as alluded to above, the success of solving a nonroutine problem is not reliant on prior mathematical knowledge. Thus, all students are given an equal chance or opportunity for success. Second, in routine problem solving, solution processes may be carried out automatically and the probability of documenting metacognitive decision-making would be minimal. By using a challenging, nonstandard task the likelihood of documenting metacognitive activity is increased.

While a nonroutine word problem minimizes the influence of school-based experience, it does not rule out the influence of nonschool-based experience. The effects of nonschool-based experience are random enough across groups to not have confounded the results of this study but have important implications for the study's generalizability to male students. Problem solving also occurs in nonacademic settings and research has documented the importance of socially-promoted gender differences in such skills, as discussed in the following section.

Generalizability across gender.

A second limitation of this study is the potential to generalize the results to male students. All participants in this study were female.

The bounty of evidence which documents differences between male and female students' perception, motivation, achievement, and academic behavior cannot be overlooked. Meece and Courtney (1992) state:

> Because women in our society are typically stereotyped as less competent than men, these sex-typed beliefs, if incorporated into the self-perceptions of girls, can lead girls to have less confidence than boys in their intellectual capacities (p. 212).

This is particularly true in mathematics, a "male domain." Boys are more confident in their math abilities than girls (Pajares & Miller, 1994) and are more likely to believe that their ability is responsible for math success (Stipek & Gralinski, 1991). Boys also place more importance on getting good grades in mathematics than girls, and see math as relevant to future career goals (Meece & Courtney, 1992).

In short, boys and girls enter the mathematical problem-solving context with a different set of self-beliefs, values, and schemata. These differences seem heavily weighed by sociocultural influences. Generally speaking, girls are trained to be rule dependent while boys are expected to be autonomous thinkers (Tittle, 1986). In fostering autonomy, boys have more access to problem-solving experiences outside of the math classroom than girls (Hyde, Fennema, & Lamon, 1990, cited in Randhawa, 1994). The differential access to nonschool-based opportunities in problem solving may help explain why boys are more likely to opt for unconventional strategies during problem solving while girls seek algorithms- each makes use of their experiential knowledge (Gallagher & DeLisi, 1994; Tittle, 1986). Given that boys have the advantage of solving problems outside of the school setting, nonroutine problem solving is more likely to be within their repetoire. Randhawa (1994) examined gender differences in problem solving using 28 mathematical word problems which reflected everyday, real-world situations. The study found that high school boys possessed greater procedural knowledge of problem solving and were more skillful in translation than girls. On the other hand, girls were better in mental computing than boys. There were no differences in the use of heuristics or monitoring strategies, or in the percentages of correct solutions between boys and girls.

In short, problem-type (and classroom context) must allow for prior sociocultural experiences to maximize the likelihood for success for both genders. Since the present study utilized a nonroutine word problem it is possible that male students may have fared better than the female students here. However, it seems that while the means used by boys and girls may differ, the ends are the same.

The relevance of prior mathematical knowledge.

As found in this study, standardized math scores were not predictive of problem-solving progress. There are two limitations to this finding. First, scores from the COOP test are an aggregate of computation and problem solving, and not a "pure" measure of problem-solving ability. Second, the task used in this study was a nonroutine word problem which involves little computation and is not similiar to the algorithmic word problems often found on standardized tests.

One would not predict that "prior knowledge" is inconsequential to problem-solving but rather that routine and nonroutine problem solving require different types of knowledge and standardized test scores are not an adequate measure of the latter. One might also predict that prior knowledge for doing nonroutine word problems is a function of training rather than "pure" math ability. Although not examined here, mathematical expertise would play a role in the metacognitive activities used to solve this nonroutine problem. An "expert" would perhaps read the problem, recognize that the value of the coins must be a multiple of five in order to equal one dollar and that most of the coins to be used would be pennies. Only after this analysis might the mathematician make a logical guess. That the "expert" may approach this problem differently than a ninth-grade math student may have less to do with mathematical knowledge (presumably, by age fourteen one's knowledge of monetary units has reached a ceiling) than with mathematical training. Whereas the mathematician is trained to have an analytical eye, the high school student is trained to do math algorithmically. The context of classroom problem solving, i.e., step-by-step approaches towards a solution with no forks along the path, is not a learning experience that is transferable to this type of nonroutine problem. For instance, one student after reading the problem wrote, "let x represent the number of coins." Since there were four types of coins that had to be accounted for, one variable (x) was an insufficient translation.

The training that students receive for solving word problems (both within and outside of school) was also not an aspect of the present study, though a viable area for future research. One could speculate that a better predictor of problem-solving success would be the math class to which students belong. Math class incorporates a medley of social and academic factors which contribute to performance. The content and purpose of the top, average, and low math classes may differ in relation to the promotion of metacognitive skills. In fact, students from the two average math classes had higher metacognitive scores (M = 6.77, sd = 2.0, n = 13) than students from the two lower math classes (M = 2.86, sd = 2.7, n = 7), and students from the top math group (M = 5.90, sd = 3.5, n = 10) did not differ from any other group. These differences were significant, $F(2,27) = 4.81$, $p = .016$. Future research would contribute to understanding how classroom processes affect metacognitive development by studying these processes within actual contexts of learning, particularly as a function of classroom emphasis.

In summary, there were several limitations to this study, as discussed. These limitations place restrictions on the generalizability of the findings to routine mathematical problems and to male students, and question the relevance of prior knowledge as measured by standardized tests. These restrictions should be kept in mind in reading the ensuing discussion.

Attributions in the domain of mathematical problem solving

Effort and ability attributions have long been an area of study. Weiner's model asserts that attributing success to ability reinforces one's pride and attributing failure to effort empowers one to face future challenges. Correlational research indicates that attributing failure to effort and success to ability is characteristic of the more mature learner. However, while motivation is a key variable in predicting academic outcomes, it is not sufficient. Gains in achievement imply gains in learning, and learning does not occur through volition alone. Learning is accompanied by the use of strategies, and ascribing to the belief that strategies are causal to performance suggests an awareness of the learning process.

Strategy versus effort attributions.

Students who recognized the role of strategies in accounting for their performance, independently from or in addition to effort, were expected to be more likely to monitor and regulate the strategies they used during problem solving and solve the Banker problem than students who ascribed to effort. Students who believed that effort was the primary source of success or failure had a misperception of the requirements of problem solving. These students were expected to traverse down a cognitive problem-solving path that would ultimately lead to a dead-end. The predictions were partially supported. Although there were no differences in overall metacognitive involvement between the three attribution groups, there were differences in a key metacognitive component- exploration. Students from the Strategy-only group were much more likely to regulate their exploration than the Effort or Unknown group. Since exploration occurred most frequently for those with the highest problem-solving progress, it was not surprising that students from the Strategy-only group were also more likely to solve the problem than the Effort group. In short, only students who did <u>not</u> attribute success or failure to effort and <u>did</u> attribute success to strategy were more likely to regulate their exploration and solve the problem. The dual attribution pattern of strategy and effort was not as adaptive as "pure" strategy ascriptions, and was no more adaptive than effort attributions alone. Presumably, had the Strategy group only included those with a "pure" strategy belief, differences on overall metacognition would have emerged. However, overall metacognition was not the best predictor of problem solving, and differences in exploration and problem-solving progress did support the predictions.

Unknown control attributions.

Students who attribute performance to unknown causes were thought to have the least amount of awareness of the learning process, and were expected to accomplish even less than those who attributed performance to effort. The results of Phase One suggested that unknown attributions were negatively related to metacognition. However, in Phase Two, the Unknown group did not differ from the Effort or Strategy group in their use of metacognitive activities (with the exception of exploration). The mixed findings of Phase One and Two may be in accord with the predictions.

Being unable to locate a cause for one's success or failure seems to imply that the process of learning was acted out with little monitoring of the activities that brought one to the place of success or failure. Students who do not know why they succeed or fail would be unaware of the strategies that led to either success or failure. Metacognition in Phase One was measured with a questionnaire which assumes students are aware of what they do while solving a problem. The Unknown group reported in Phase One that they did not use metacognitive strategies for solving math word problems. However, by observing the problem-solving processes it was apparent that these students did utilize metacognitive strategies. The think aloud procedure measures what students actually do while solving the problem, rather than their awareness of what they do, thus, one would not expect the metacognitive data from Phase One and Phase Two to necessarily be consistent. That is, if unknown attributions are a proxy for a lack of metacognitive awareness one would not expect students to know, that is be able to report, the strategies they use. One can use a strategy and not be aware that s/he is using it. Research that is based on metacognitive awareness differs both conceptually and methodologically from research based on metacognitive activity. The two may yield different outcomes.

This explanation may offer a partial account of the discrepancy between the Unknown groups' metacognitive awareness during Phase One and metacognitive activity during Phase Two; it does not, however, explain why the Effort group did not outperform the Unknown group, as was predicted. While the Unknown group may not be aware of the strategies they use, at least enough to give a retrospective account of them, their performance was no different from that of the Effort or Strategy group, and in fact was more similar to that of the Strategy group. Their "unknowing" did not debilitate them from trying or from exploring possible paths. Why, then, were these students not able to solve the problem? Simply put, they were not regulating their exploration. They utilized a guess-and-test approach. It is possible that with more time, however, these students would have solved the problem. With the exception of one student who gave up (there was one student from each of the three groups who gave up), and three students who thought they had the correct answer, the remaining six students were still deeply engaged in the problem at the end of twenty minutes. Conversely, students who attributed their performance to effort spent the least amount of time on the problem and thought they solved the problem when they did not.

In considering the possibility that a greater allotment of time may have lead to different findings, i.e., that the Unknown groups' persistence may have proved successful, one can speculate that perhaps students were unable to locate a cause of their performance because they did not have the time needed to complete a solution process, and thus did not have the time to reflect upon the strategies used. One could further speculate that these students are not very confident about tasks that have time limits or that involve reflection. In this study perhaps one indication of confidence were attributions to ability.

Ability attributions.

Students from the Unknown group did not attribute success at solving math word problems to ability (M= 3.8), a significant difference ($F(2,27) = 3.644$, $p = .04$) from the combined strategy group ($M = 2.6$). However, while students from the Unknown group did not attribute success to ability their problem-solving progress scores were no different from the other groups who did attribute success to ability (Strategy-only, 2.8; Strategy-Effort, 2.4; and Effort, 2.9). While the Success-Strategy and Success-Ability responses were positively related (r = .5617, $p < .001$), the former was more predictive of problem-solving success.

Unlike the findings of previous studies, attributing success to ability seemed to have no bearing on the results. However, caution is needed in interpreting this result since ability attributions were not the focus of this study and this result is based on responses to one item. Nonetheless, unlike Weiner's claim that ability is one of the four most frequently cited causes for performance, ability attributions made up less than one percent of the open-ended attribution responses in this study. Students were much more likely to attribute success to a problem-solving strategy than to ability, or to effort, when their responses were not restricted to a forced-choice format, and this finding was true for open-ended responses given prior to, and after, the task. The prevalence of ability and effort attributions seems related to the methodologies relied on. As Rohrkemper (1989) suggests, attributions measured during the problem-solving process differ from those which require a retrospective or hypothetical account of performance (see Attributions and Assessment).

Attributions for failure.

Attributing failure to strategy did not have the same predictive power as attributing success to strategy. Students were much less likely to believe that an unsuccessful problem-solving attempt was the result of not following the right procedure. Rather, the open-ended items indicated that students perceived failure to be the result of not understanding the problem (a realistic interpretation of failure to solve the problem, as will be discussed). Given the results of prior research which indicates that attributing failure to strategy is related to persistence, expectancies of success, and achievement, the findings here were unexpected. Two explanations are offerred.

First, Weiner (1985b) claims that causal search is triggered by an unexpected outcome, usually interpreted as "failure." However, is a causal search elicited if failure is expected? A student who expects failure, or at least is unsure of success, does not experience a discrepancy, or the need to reconceptualize the event, when failure occurs. Expectations of failure may also be accompanied by high emotionality which may hinder or overshadow the reflective process. Conversely, students who expect success and then do not succeed experience a discrepancy which may elicit a search for explanation. They may also have low levels of affective interference during problem solving and thus may be more aware of the strategies used.

Second, the low occurrence of failure strategy attributions may account for the insignficant findings. Students may not be willing to take responsibility for not following the right procedure unless they know what the right procedure is. Past studies which assess attributions to strategy do so in relation to strategy instruction. An interesting study for future research would be to determine how expectations of success or failure are related to metacognitive and attributional process during problem solving and how the inter-relationship among these variables develops with strategy instruction. The study of attributions during actual task performance is likely to yield different results from studies which employ different methodologies. Differences across studies may be the result of assessment differences.

Attribution assessment.

Vispoel and Austin (1995) highlight three methodological approaches to attribution research-situational (state), dispositional (trait), and critical incident. A situational approach requires either a specific hypothetical situation or an experimentally contrived task. The outcome of the achievement event is manipulated and often students choose among experimenter-defined causes. A dispositional approach also involves hypothetical situations but seeks generalization across domains. Both of the above-mentioned approaches assume that students' responses to hypothetical or contrived situations parallel the causal ascriptions which occur in reaction to a real-life event. The final approach, critical incident, does not make this assumption but rather avoids it by studying attributions in relation to actual (Type I) or recalled (Type II) performance on a real-life classroom task.

Vispoel and Austin (1995) conducted a study which used the Type II critical incident approach. They were interested in addressing the following questions- Do attributions vary as a function of outcome and subject area?; Are attributions related to grades within the subject areas?; To what degree do the dimension of locus, stability, and controllability classify attributions about real-life events? To answer these questions junior high school students were asked to recall a classroom activity in either English, math, music, or physical education in which they either did well or poorly. Students then stated their agreement or disagreement on a typical 6-point Likert scale continuum to eight attribution statements (ability, effort, strategy, interest, task difficulty, luck, family influence, and teacher influence). Only findings which are relevant to this discussion are noted.

First, regardless of subject area, students were most likely to endorse effort for their success. In the present study, students were more likely to attribute success to using the right strategy than to trying hard. The difference in findings may be the result of methodology. Vispoel and Austin employed a Type II critical incident approach (recalled performance); here a Type I critical incident approach (actual performance) was employed. As Rohrkemper (1986) points out- students' attributions, when measured "in action," that is, during problem solution, may differ than when assessed in relation to past performance.

Second, they found that success effort attributions were positively related to course grades in all four subject areas. Success strategy attributions were only positively related to English and physical education grades but not math or music grades. In the present study, success effort attributions were inversely related to problem-solving progress and success strategy attributions, though not significantly related to problem solving, were in a positive direction. Again it seems that effort is more clearly related to global performance while strategy is related to specific tasks and must occur simultaneously with strategy instruction for students to recognize the causal connection.

Third, bipolar factors of locus, stability, and controllability were not found for success or failure. Rather a factor analysis forming nine factors suggested that internal attributions (ability, effort, strategy and interest) "hung" together but were domain-specific and external attributions (task difficulty, luck, family and teacher influence) tended to generalize across domains. Conversely, the present study clearly demonstrated the need to separate effort and strategy (both internal, controllable, unstable factors) and in fact, a factor analysis using data from 49 students who met the selection criteria of this study formed two factors. On factor 1, failure-effort and success-effort loaded positively (.766 and .783, respectively) and failure-unknown and success-unknown loaded negatively (-.676 and -.639). On factor 2, failure-strategy and success-strategy loaded positively (.805 and .857, respectively). Again the differences between Vispoel's study and the present one is most likely the result of data obtained from specific task performance versus recalled performance.

In conclusion, conflicting research findings may be, in part, the result of assessment procedures. Future research should consider the methodologies as highlighted by Vispoel and Ausin (1995) when interpreting their findings.

Strategies used for problem solving

Only four students solved the problem within the allotted time, that is received a problem-solving score of four or five; seven solved the problem with some degree of prompting. Among the successful problem solvers there were several similarities. First, they had a sound cognitive understanding of the problem's conditions and goal although they did not necessarily monitor their understanding of the problem. Second, they monitored and regulated their exploration, that is, used a guess and test approach and made new guesses based on the results of the tests. However, while the Banker problem is conducive to a guess-and-test approach, students who solved for coins and then tested the value, or vice versa, left more room for error and/or more of a chance to forget about the factor not being guessed at. This was less true for students who kept track of both the coins and the value simultaneously. Third, they did not (except for one) analyze the problem, make a plan, or completely verify their solution. Fourth, three were from the Strategy-only attribution group. In short, Exploration, and specifically the regulation of exploration, was the key metacognitive aspect of the problem-solving process.

Comparisons of good and poor readers indicate that poor readers are likely to evaluate their comprehension, e.g., become aware of an unknown word; however, they are less likely to regulate or "fix" their lack of comprehension (Zabrucky & Ratner, 1986). Good readers utilize the results of their evaluations. Similar differences in mathematical problem solving were found in this study. Successful problem solvers' exploration was metacognitive throughout, an ongoing regulation of attempts. Unsuccessful students fluctuated between cognitive (guessing) and metacognitive (testing). Figures 5 and 6 illustrate the metacognitive processes of a successful and an unsuccessful problem solver, respectively.

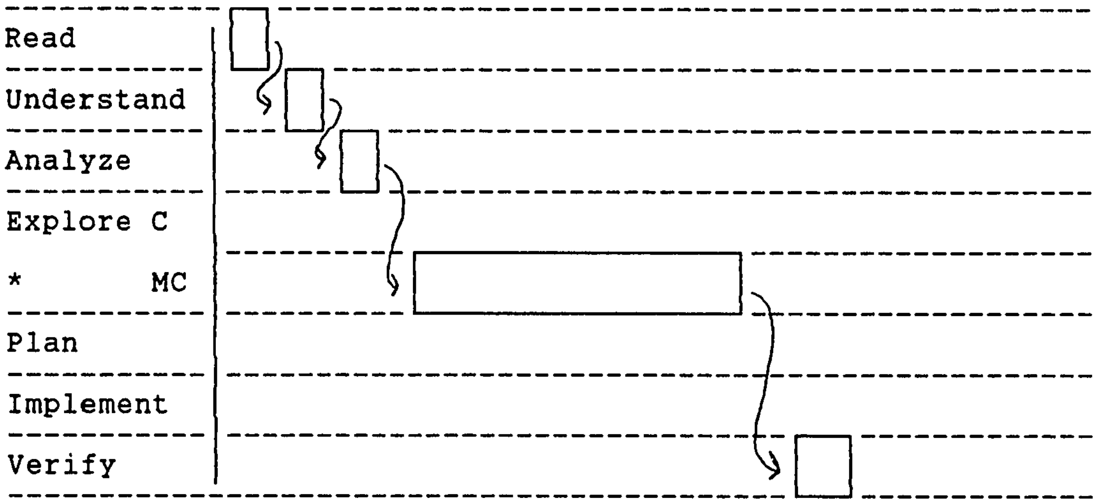


Figure 5. Metacognitive processes of a successful problem solver.

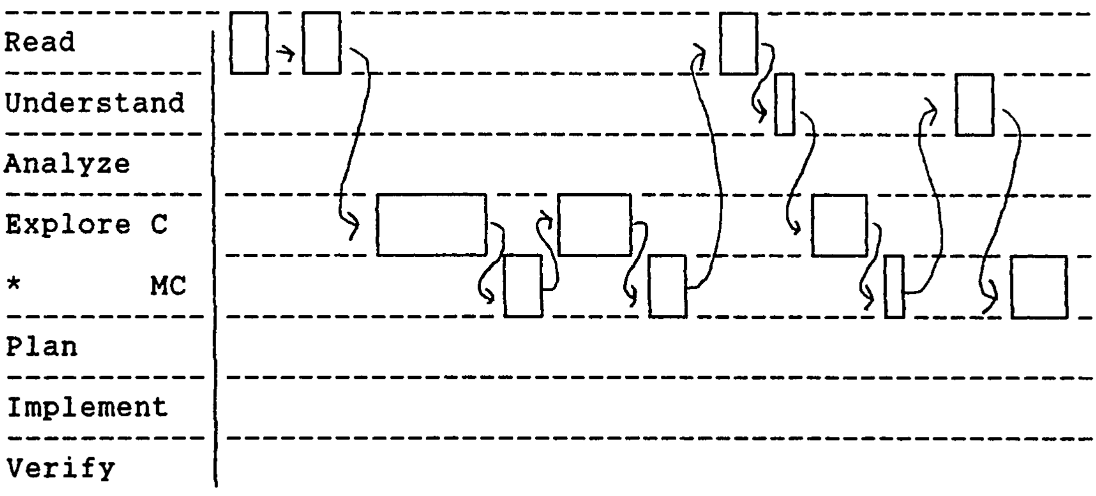


Figure 6. Metacognitive processes of an unsuccessful problem solver.

Metacognitive assessment.

As with any covert variable, the problem of assessment accuracy arises. Metacognition can be assessed on a questionnaire or in an interview asking students to report the types of metacognitive strategies which they use when carrying out specific tasks. Both procedures involve some degree of retrospection and raise concerns of accuracy and honesty, though the interview has the advantage of immediate inquiry if following a task performance. Metacognition can also be assessed on-line, that is, during activity. This can be accomplished with a concurrent interview or with the observation of spontaneous private speech (Meichenbaum, Burland, Gruson, & Cameron, 1985). A second way to assess on-line metacognition is to observe and record behavior. This is particularly relevant when the behavior is motoric, i.e., involves tangibles. When the behavior is covert, such as mathematical problem solving, a think aloud procedure verified with videorecordings of the problem-solving session seems a valid alternative.

In the present investigation, a total metacognitive score was not a true indicator of problem-solving success since neither Metacognitive Understanding, Planning, or Verifying were necessary for solving this problem. Fifty-seven percent of the participants did little to no monitoring of their understanding; 93% did not devise a plan; and 73% did not verify their solutions. While

Analyzing was significantly correlated to problem-solving progress ($r = .343$, $p < .01$) it was also not necessary for a correct solution; 63% of students did not analyze the problem. The caveat in drawing the above conclusions is that one cannot infer that a lack of verbalization reflects an absence of metacognitive thought (Taylor & Dionne, 1994). The language that one is able to express may or may not be an exact account one's mental processes. The validity of findings which are based on a think aloud procedure alone would be questionnable. However, this study attempted to enhance the validity of metacognitive assessment by including a videorecording of the problem-solving session. Protocols were based on verbal and written data. Initial transcripts were based on a verbatim translation of audio-taped recordings. The transcripts were then matched against the audio component of the videorecording for greater accuracy. Statements were parsed according to cognitive and metacognitive processes yielding a solution pattern. The videotapes were also analyzed for a solution pattern. The patterns yielded from the audio and video transcripts were then matched and discrepancies were re-analyzed. Written protocols were utilized for clarity if students' writing was unrecognizable from the videotapes. While there is no surefire way of judging the accuracy of the above-mentioned assessment procedure it is the contention of the author that 85-90% of metacognitive activity was captured.

Verification.

Unlike in Phase Two, verification was significantly related to problem-solving progress (r = .566, p < .001) in Phase Three. There was also a significant correlation between the type of prompt one received and the gains made in verification (r = -.640, p < .01). The level of prompting was scored from least to most direct, as follows: indirect prompt = 1; reading prompt = 2; direct prompt = 3. The type of prompt was also used categorically. Students who received either a reading prompt or a direct understanding prompt were no more likely to verify the second time around. Conversely, students who were indirectly prompted to explain their answer, after realizing almost independently that they had not solved the problem, were much more aware that verification was needed the second time around. An analysis of variance confirmed this result, $F(2,12)$ = 5.07, p = .025). The mean gain for students receiving this indirect prompt was 2.75, compared to .75 for a reading prompt and .286 for a direct prompt. Students who needed a direct prompt did not have a clear mental representation of the problem and thus had no basis for making a comparison between their answer and the requirements of the problem; they thought they had solved the problem. For this group of students, verification, particularly going back to the problem, appears critical. Conversely, students who had a cognitive understanding of the problem, when asked to explain how they derived their answer, did not go back to the problem to verify. They (almost) immediately recognized a discrepancy between their answer and the problem stipulations. Metacognitive support was effective when the student had a cognitive base, an accurate understanding and representation of the problem.

In short, students who solved the problem the first time had a clear understanding of the problem and verification either occurred on a more covert level or was not needed since they were regulating their attempts throughout. Students who solved the problem on the second trial (Phase Three) also had a clear understanding of the problem but were not regulating their exploration. However, with an indirect prompt (e.g., "Tell me what you did."), they quickly became aware of their errors, verified their solution and then began regulating their exploration. Finally, students who did not solve the problem appear to be of two categories: 1. they did not understand the problem or 2. they understood the problem but were engaged in a cognitive problem-solving endeavor with no metacognitive monitoring.

Cognitive strategies.

The Banker problem involved a minimum of cognitive activity. Students had to read the problem, understand the three problem conditions and goal, and engage in basic math (addition and subtraction). Students employed several additional cognitive strategies. For instance, many students drew circles to represent the coins; some used tally marks. One student said, "I used pictures and images of the number of coins I still had in my hand." Another student began with a variation of coins that equalled one dollar. She kept replacing the larger valued coins for smaller ones until she had fifty coins. However, at one point she crossed out a dime and only replaced one nickel. She lost track of this cognitive endeavor; she scored a four on problem solving.

There were several cognitive approaches to solving this problem. All seemed equally effective to the extent that students were keeping track of their cognitive progress, that is, were metacognitive.

Implications for future research and educational practice

In summary, the first aspect of this study challenges the motivational importance of ascriptions to effort as causal to successful performance. Attributing problem-solving performance to effort was inversely related to actual performance and to metacognition. The prevailing notion is that effort attributions, because of their internal and controllable nature, are beneficial for students to uphold. However, self-worth theory postulates that high effort implies low ability. Self-regulation theory holds that effort is too vague a construct to provide any information about the "hows" of learning. An important area for future research is to delineate the exact perceptions that students have of "effort." "Effort" appears to be an inexact account of the learning process. While "putting one's mind to it" may be the impetus of learning, volition alone will not guarantee learning without the accompaniment of strategies. Future research would contribute greatly to this understanding by studying students' perceptions of effort as related to contextual learning and motivational outcomes.

Also, given that attributions to strategy alone seemed most adaptive to the outcomes of this study, attribution re-training should reconsider combined strategy and effort feedback. Strategy attributions, particularly for success, appear most adaptive for mathematical problem solving and may be of a "meta" nature, that is, arise as an integral part of the metacognitive system. As found here, students who had high metacognitive scores were more likely to attribute their success to using a specific strategy, such as drawing a chart, than students with low metacognitive scores. Students who are consciously and actively involved in learning are aware of the strategies they use and attribute success to using the right strategy. Future studies might set out to determine at what point in the learning process students begin to account for their successes with strategies. Does success have to occur repeatedly with the same task? Is there a trend in the onset of strategy attributions that parallels the development of the metacognitive system?

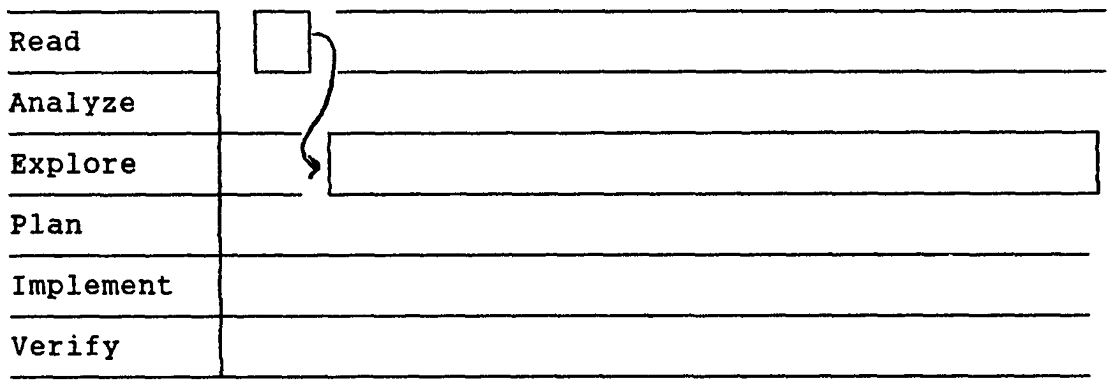
Future research should also investigate the effects of attributing failure to strategy. Saying, "I failed because I didn't use the strategy that I was taught," or, "I failed because I didn't follow the right procedure," may have damaging effects on students confidence when such statements admit to a lack of knowledge. However, it also seems that strategy statements have positive consequences for learning, particularly when linked to strategy instruction. Attributions to strategy may be possible in a classroom where ability is not a salient feature for judging performance. An environment that is conducive to analyzing one's errors without harming one's self-perceptions may be created by adopting a policy on grading that is not based on performance as the end goal but that incorporates students' progress and provides feedback to the learner that is specific and strategy-based. Individual differences in the amount of feedback and social support students need, the level of structure given, and the amount of time students require to accomplish a task could be accepted as an integral part of the classroom environment. As discussed earlier, unknown attributions may stem from students not being able to locate a particular cause for performance because they simply have not been allotted the time they need for such reflection. Also, the expectancies which students, particularly girls, bring to the math classroom should not be ignored. Girls and boys have different nonschool-based oppurtunities for problem solving which should be considered so that success across gender is maximized. One suggestion is to incorporate both routine and nonroutine problem types in the classroom and focus on the processes of problem solving as a creative endeavor and not solely a means to an end.

Studies which examine teaching methods facilitative of this reflection process in math would be beneficial for educational practice. Clearly, mathematical problem solving in today's classroom is far from being the scientific process that many had envisioned, i.e., Lakatos, Polya, Dewey. As the present study demonstrated, the majority of students did not devise a plan for the problem, analyze the problem, or even verify their solutions. Why would students engage in these activities when their experience of word problems dictates quite a different approach? Magdalene Lampert (1990) is examining some alternative activities for doing mathematics. In her classroom students are immersed in a culture of expert practice, here that of mathematician, that is socially supported and augmented by role switching between teacher and students. Analysis of errors is encouraged. The focus is not on right or wrong answers but on the inductive analysis that lead one to their answer. Required of the teacher is not only an in-depth knowledge of the content, but a historical knowledge of the development of the field, and a belief that students "grow into the intellectual life around them" (Vygotsky, 1978).

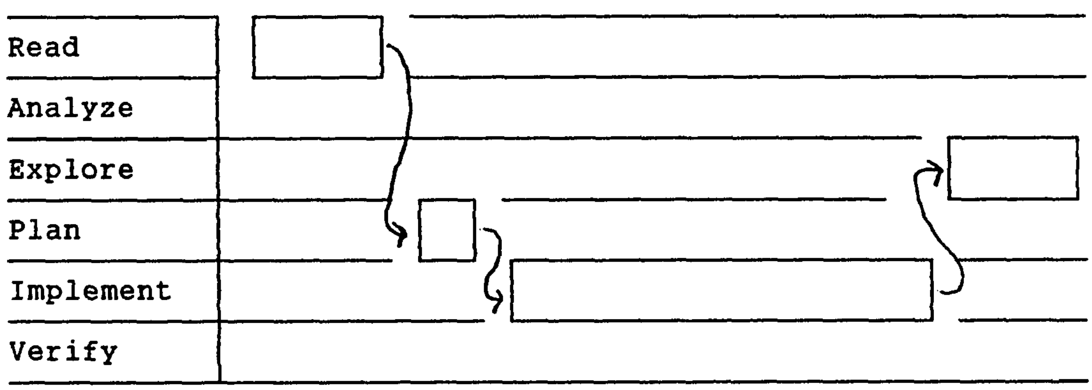
Teachers are the intellectual life of students for close to eight hours a day. At minimum, teachers can maximize their role as models. In the classroom, teachers can engage in think alouds where solution processes are highlighted, including errors and including attributions to strategies. Classroom methods that incorporate both cognitive and attributional processes are compatible with the types of activities and mathematical community Lampert discusses. Educators must be cognizant of the strategies they teach and also must recognize the impact that causal beliefs have on performance as well as on motivation, attitudes and expectations for future success. More specifically, it is suggested that educators draw students' attention to the role of strategies as a controllable, flexible and developmental aspect of the learning process.

APPENDIX A

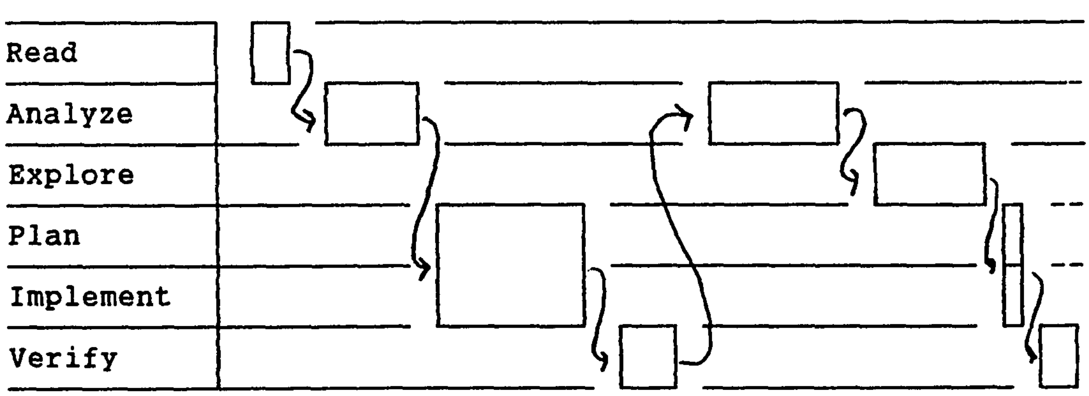
A TIME LINE REPRESENTATION OF NOVICE AND EXPERT PROBLEM SOLVING EPISODES



Example 1: Novice



Example 2: Novice at later stage



Example 3: Expert

(adapted from Schoenfeld, 1985)

APPENDIX B

DEFINITIONS OF METACOGNITIVE AND COGNITIVE EPISODES FOR THE BANKER PROBLEM

A banker must make change of one dollar using 50 coins. The banker must use at least one quarter, one dime, one nickel, and one penny. How many of each coin must the banker use to do this?

READ (Cognitive): The student must read or listen to someone else read the problem.

UNDERSTAND (Cognitive): Student's approach to problem indicates understanding of the conditions and goal of the problem.

(Metacognitive): The student must verbalize their awareness, or monitor their understanding of the conditions and goal of the problem.

1. There must be a total of 50 coins
2. The value of the coins must equal $1.00
3. One quarter, one dime, one nickel, and one penny MUST be used
4. Goal: How many of each coin will the banker use?

ANALYZE: (Cognitive or metacognitive): Analysis is metacognitive when student's examination of the problem is reasonable, explicit, and followed through.

1. The problem can be reformulated to four coins (1 quarter, 1 dime, 1 nickel, and 1 penny) have the value of 25 + 10 + 5 + 1 or 41 cents so 46 coins must be used that equal 59 cents.

2. Because quarters, dime, and nickels are all multiples of five, their sums will be a multiple of five. Because the sum must be 100, also a multiple of five, the number of pennies used must also be a multiple of five.

3. For fifty coins to be worth $1.00, most of the coins selected will be pennies AND very few quarters will be used.

APPENDIX B (continued)

COGNITIVE EXPLORATION: Cognitive exploration involves the use of cognitive strategies, such as, adding, subtracting, making guesses and mathematically testing those guesses. If the student is not keeping track of their cognitive activity, he/she is embarking on an unmonitored exploration.

METACOGNITIVE EXPLORATION: If a student is using a guess-and-test approach the student is evaluating the results of an attempt; an even deeper involvement would be when new guesses are based on the results of old ones, then he/she is evaluating and regulating the exploration (called building).

PLANNING: Planning by definition (Jacobs & Paris, 1987) is metacognitive, if explicit. The student may:

1. Divide $1.00 into four quarters. Leave one quarter, and keep breaking down the remaining quarters until there are 50 coins.

2. Make a chart using headings for the types of coins to keep track of how many coins of each have been used.

3. Start with pennies and exchange the pennies for other coins.

IMPLEMENT: Implementation may involve the same cognitive activity as in exploration but is distinguished as being the result of a specific plan rather than the result of guessing and testing. If the implementation of a plan is systematically monitored (metacognitive), the student is more likely to recognize when the plan must be relinquished for a better plan. If the implementation is not monitored it is cognitive alone.

VERIFY: The student must be able to take the final solution and check that the number of coins is 50 and that the total value is $1.00, and that one of each type of coin was used. This process involves adding numbers (cognitive) and the ability to check or monitor that all three conditions have been met (metacognitive). Also the numerical verification may other regulatory activities, such as, re-reading the problem or verifying one's understanding of the problem (metacognitive).

APPENDIX C

MAQ ATTRIBUTION STATEMENTS

<u>DURING CLASS</u>
Unknown Control

21. When I correctly answer a question my teacher asks about word problems, I usually do not know why I get it right.

30. I usually do not know what is going on when my teacher is explaining a word problem.

34. I do not know why I cannot follow the word problems my teacher works on the board.

Internal Stable Controllable

38. If I understand a word problem my teacher is explaining, it is because I am trying as hard as I can.

40. The next time my math teacher explains a word problem to the class, I expect to understand because I always listen carefully.

41. Because I pay attention, I know I will be able to understand the word problems my teacher explains in class.

APPENDIX D

MATHEMATICAL WORD PROBLEMS (Primer)

Name ____________________________ Date ____________

Teacher _________________________ Grade ___________

Math class _____________________

THIS IS JUST A PRACTICE WORD PROBLEM. PLEASE TALK OUT LOUD WHILE YOU ARE SOLVING THIS PROBLEM.

Eight pennies are arranged in a row on a table. Every other coin is replaced with a nickel. What is the total value of the coins on the table?

APPENDIX D (continued)

MATHEMATICAL WORD PROBLEMS (Banker problem)

Name ____________________________ Date ____________

Teacher _________________________ Grade ___________

Math class _____________________

Please read the problem and try your best to solve it. You will not be graded on this problem and it will not affect your schoolwork in any way. You can use this sheet as scrap. DON'T FORGET TO TALK OUT LOUD WHILE YOU ARE WORKING THIS PROBLEM. If you make a mistake put a line through the mistake and go on.

A banker must make change of one dollar using 50 coins. The banker must use at least one quarter, one dime, one nickel, and one penny. How many of each coin must the banker use to do this?

APPENDIX E

PARENT/STUDENT CONSENT FORM

Dear Parent,

I am a graduate student at the City University of New York and am currently working on my dissertation. I have received the cooperation of Sister ------ to work with the ninth-grade students at ----- and would like your daughter to participate in a project on mathematical problem solving.

The project will take place at ------, during school hours. The purpose of the project is to gain information about how high school girls approach mathematical word problems. I will not be testing your daughter's math ability but am interested in how she thinks about math problems. The session(s) will be videotaped, however, only the students' handwriting will be captured on the tape (your daughter's anonymity will be protected). I would also like permission to obtain your daughter's most recent math test scores and grades.

Your daughter's participation in this project is voluntary and would in no way affect her grades or school work in a negative way. Any information that I obtain will be kept confidential. Your child's anonymity will be protected, and she is free to withdraw from participating at any time.

If you give permission for your daughter to participate, and your daughter also agrees, please sign below.

Thank you.

Cordially,

Dana Fusco

I agree to participate in this project.

Date ______________

Signature of Parent ____

Signature of Student ______________________________________

APPENDIX F

STUDENT AGREEMENT FORM

I, ________________________________, agree not to tell my friends, or any of the students in my math class, about the study that I participated in until everyone has had the opportunity to participate. I understand that by talking to my peers about what transpired that I am giving them an advantage that I myself did not have, and that by sharing any information I would be jeopardizing the results of the study.

Date _________________

Signed ____

Witnessed by ____________________________________

APPENDIX G

ATTRIBUTION QUESTIONNAIRE FOR MATHEMATICAL PROBLEM SOLVING

Name ______________________________ Grade __________________

Age ____________________ Male or Female (circle)

Teacher ___________________________ Class __________________

Date __________________

The questions on the next page ask about what you think and how you feel about doing mathematical word problems. There are no right answers. You will not be graded on your answers and the information will not affect your grades or school work. Please answer each question as carefully as you can by CIRCLING the number that says how true the item is for you.

PLEASE READ THIS SAMPLE MATH WORD PROBLEM BEFORE GOING ON.

Sleepy Cat

A sleepy cat wants to climb to the top of a tree that is 10 meters tall. Each day the cat climbs up 5 meters, but at night, while asleep, it slides back 4 meters. At this rate, how many days will it take the cat to reach the top?

1 Very True	2 True	3 Sort of True	4 Not Very True	5 Not at all True

1. If I did not solve a math word problem it was because I did not try hard enough.
1 2 3 4 5

2. I get nervous right before I have to solve a word problem.
1 2 3 4 5

3. If I cannot solve a word problem it's because I do not know a good way to solve it.
1 2 3 4 5

4. If I get a word problem wrong I usually do not know the reason why.
1 2 3 4 5

5. When I am able to solve a word problem it is because I really put my mind to it.
1 2 3 4 5

6. I won't be able to solve the word problem if I don't put in the effort.
1 2 3 4 5

7. If I didn't have a good procedure for doing a word problem I probably wasn't able to solve it.
1 2 3 4 5

8. If I get a math word problem right it's hard to figure out the reason.
1 2 3 4 5

9. Before I begin a word problem I think about if I understand what the problem is asking me.
1 2 3 4 5

10. If I get a word problem right it's because I followed the steps I was shown.
1 2 3 4 5

11. If I was not able to solve the word problem it was because I didn't put my mind to it.
1 2 3 4 5

12. After I solve a word problem I go back and check my work.
1 2 3 4 5

1 Very True	2 True	3 Sort of True	4 Not Very True	5 Not at all True

13. If I solve a word problem it was the result of my effort.

1 2 3 4 5

14. If I get a math word problem right it's because I am good at them.

1 2 3 4 5

15. When I am able to solve a word problem it is because I used the right procedure.

1 2 3 4 5

16. If I cannot solve a math word problem it's because I didn't follow the steps I was taught.

1 2 3 4 5

17. If I get the word problem incorrect it's hard to tell why this happens.

1 2 3 4 5

18. If I try hard enough I will be able to get a math word problem right.

1 2 3 4 5

19. When I get a word problem correct I do not know why.

1 2 3 4 5

20. If I do not get a word problem right it's because I was never good at solving problems.

1 2 3 4 5

21. If I was able to solve the word problem it was because I had a good strategy or way to solve it.

1 2 3 4 5

22. When I'm having a hard time trying to solve a problem I start planning a different approach.

1 2 3 4 5

23. When you cannot solve a word problem why do you think this happens? ____

____

24. When you can solve a word problem why do you think this happens? ____

____

APPENDIX H

ITEM-SUBSCALE BREAKDOWNS

FAILEFF

1. If I did not solve a math word problem it was because I did not try hard enough.

6. I won't be able to solve the word problem if I don't put in the effort.

11. If I was not able to solve the word problem it was because I didn't put my mind to it.

SUCCEFF

5. When I am able to solve a word problem it is because I really put my mind to it.

13. If I solve a word problem it was the result of my effort.

18. If I try hard enough I will be able to get a math word problem right.

FAILSTRA

3. If I cannot solve a word problem it's because I do not know a good way to solve it.

7. If I didn't have a good procedure for doing a word problem I probably wasn't able to solve it.

16. If I cannot solve a math word problem it's because I didn't follow the steps I was taught.

SUCCSTRA

10. If I get a word problem right it's because I followed the steps I was shown.

15. When I am able to solve a word problem it is because I used the right procedure.

21. If I was able to solve the word problem it was because I had a good strategy or way to solve it.

APPENDIX H (continued)

FAILUNK

4. If I get a word problem wrong I usually do not know the reason why.

17. If I get the word problem incorrect it's hard to tell why this happens.

SUCCUNK

8. If I get a math word problem right it's hard to figure out the reason.

19. When I get a word problem correct I do not know why.

ANXIETY

2. I get nervous right before I have to solve a word problem.

ABILITY ATTRIBUTIONS

14. If I get a math word problem right it's because I am good at them.

20. If I do not get a word problem right it's because I was never good at solving problems.

METACOGNITIVE STRATEGIES

9. Before I begin a word problem I think about if I understand what the problem is asking me.

12. After I solve a word problem I go back and check my work.

22. When I'm having a hard time trying to solve a problem I start planning a different approach.

OPEN-ENDED

23. When you <u>cannot</u> solve a word problem why do you think this happens?

24. When you <u>can</u> solve a word problem why do you think this happens?

APPENDIX I

DEVELOPMENT OF THE ATTRIBUTION QUESTIONNAIRE FOR MATHEMATICAL PROBLEM SOLVING

Validity.

The content validity of the questionnaire was judged by nine experts in the field of education and educational psychology (four faculty and five doctoral students). Their task was to code the statements according to their categories (effort, strategy and unknown attributions, and filler items). Items that had lower than an 89% interrater agreement were re-written and then re-evaluated by two judges to meet 100% agreement. The judges also rated the readability of the items and instructions for high school students. All but one reviewer felt the instructions and items were either very clear or clear.

Formatting.

Two formats, a Likert-scale and a forced-choice format, were originally developed and evaluated. Seventy-eight percent of the judges regarded the Likert scale as "very clear," whereas only 44% felt similarly for the forced-choice format. The judges regarded the forced-choice items as too transparent and predictable, limiting of students' choices, and not sensitive to the possibility of agreeing with more than one choice. Conversely, the 5-point Likert-scale assesses the degree of students' attributions (How true is this for you? 1, very true; 2, true; 3, sort of true; 4, not very true; and 5, not at all true).

Reliability.

The reliability of the questionnaire was examined during pilot testing. The original version of the questionnaire included six items for each attribution scale (Strategy, Effort, and Unknown), with three items worded for success and three worded for failure. The instrument also included several filler items that assessed ability attributions, anxiety, confidence, vagueness, and strategy use. The questionnaire was group-administered to twenty-two high school students enrolled in a 9th grade Regents Algebra course in Queens, New York. There was an equal ratio of boys and girls ranging in age from 14-18 years old. The mean age was 16 and the mean grade level was 11. Based on the results of piloting several modifications were made.

1. The Unknown subscales for success and failure were significantly correlated (.7943) at the .001 level and were collapsed to form one scale. The revised version includes four rather than six items in this scale.

2. The effort items for failure were less consistent than those for success, thus the subscales were re-written to be made more parallel.

3. The strategy subscales were altered to represent general rather than specific strategies, and to be more parallel to each other.

4. The metacognitive strategy items were removed from the strategy scales to comprise a separate scale.

5. Several of the filler items were dropped (confidence, vagueness).

The revised questionnaire was re-administered to the same math class exactly three weeks later during the same class period making it possible to calculate test-retest correlations. In addition, a second math class (different teacher), of 10th graders in the general math track, also completed the revised questionnaire. The total sample was 37 high school students. Aside from one of the strategy scales, the reliabilities showed marked improvement.

	Time 1	Time 2	test-retest
Fail-strategy	.0000	.6053	.2331
Succ-strategy	.3323	.2407	.5632*
Fail-effort	.4750	.8450	.5591*
Succ-effort	.8685	.8428	.5183
Unknown	(.64, .88)	.7157	.8108**

* significant at .01 level
** significant at .001 level

The reliabilities for the Effort and Unknown subscales seem to show consistency with, and greater strength than, the reliabilities found in other measures. Connell (1985) found that the reliabilities for his Unknown control scales with junior high school students ranged from .52 to .67. The reliability found here is .71. Powers, Douglas, and Chorosky (1984), in evaluating the <u>Mathematics Attribution Scale for Algebra</u> with above average precollege students, found that the Success to Effort subscale had a reliability of .80 and the Failure to Effort subscale had a reliability of .66. The corresponding reliabilities for the present measure are .84 and .84.

While the Effort and Unknown scales seem promising, the decrease in reliability for the Succ-strategy subscale from Time 1 to Time 2 was of concern. Based on an examination of individual student responses to the three items in this scale, it was apparent that four students responded inconsistently to item 23 in comparison to their responses on items 10 and 16. When these four students' responses were removed from the analysis, the scale reliability increase to .4992, from .2407. Item 23 is a specific strategy that one would not expect to be related to more general strategy items. The main difficulty with achieving high reliability for the strategy scales seems to lie in the specific versus general nature of strategies. The items initially reflected specific strategies, such as, checking. Hecht and Tittle (1989) note that students' reported use of specific strategies differs from their use of general strategies and differs depending upon whether the activity occurred before, during, or after problem solving. Strategies, such as planning and checking, then, would emerge as two independent factors. Consequently, the items were re-written to represent general strategies.

The reliability for the Unknown scale was also not as high as expected. The item-subscale correlations showed that item nine, though significant, had the lowest correlations to the scales. Item9 reads "The next time . . . ", so is worded for future, rather than past, prediction. This item was revised.

Item-subscale Correlations

Correlations:	ITEM1	ITEM6	ITEM11	
FAILEFF	.8905**	.7932**	.9331**	
	ITEM5	ITEM14	ITEM19	
SUCCEFF	.8526**	.8786**	.8937**	
	ITEM3	ITEM7	ITEM17	
FAILSTRA	.6749**	.8784**	.6884**	
	ITEM10	ITEM16	ITEM23	
SUCCSTRA	.6992**	.5019**	.6821**	
	ITEM4	ITEM8	ITEM9	ITEM18
UNKNOWN	.7443**	.7792**	.6291**	.7868**

APPENDIX J

METACOGNITIVE CHECKLIST

Id _____ Group _____ ps _____

Understanding
1. must use 50 coins _______
2. must equal $1.00 _______
3. must use at least 1 qu, d, ni, p _______
4. goal _______

Analyzing: Did student do anything else to aid in her understanding of the problem? ______________________________

Exploring
1. guessing _______
2. testing _______
3. building _______

Verifying
1. checked no. of coins used _______
2. checked value of coins _______
3. supplied correct response (no. of each coins used) ______

Planning/implementing
evidence? _______
pursuit? _______
monitoring? _______

Change in strategy?

Read	
Understand	
Analyze	
Explore C	
MC*	
Plan	
Implement	
Verify	

APPENDIX K

POST-TASK ATTRIBUTION QUESTIONNAIRE

Name ______________________________ Class _____________

Age _____________

Ethnicity: Hispanic Caucasian Asian African-American

Other (Specify) _______________________

Did you solve the Banker problem? Yes No

Why do you think you were or were not able to solve this problem?

____

____

____

____

Which is MOST important for solving math word problems?

math ability trying hard knowing a procedure

Which is LEAST important for solving math word problems?

math ability trying hard knowing a procedure

APPENDIX L

Summary of Regression Analysis for Attribution Subscales as Predictors of Problem-Solving Progress

A regression analysis was performed using the six attribution subscales as predictors of problem-solving progress. The success-effort subscale entered on step one of the equation (R^2 = .184, *B* = .282, *SE B* = .112, *ß* = .4289). The beta's for the remaining subscales were: failure-effort, .187; failure-strategy, -.049; success-strategy, -.348; failure-unknown, .222; success-unknown, .253. (Negative beta weights indicate that attributing failure or success to strategy, low subscale score, was related to higher problem-solving scores.) The success-strategy subscale entered on step two of the equation (R^2 = .30, *B* = -.207, *SE B* = .097, *ß* = -.3485). The beta's for the remaining subscales were: failure-effort, .161; failure-strategy, .101; failure-unknown, .189; and success-unknown, .067.

APPENDIX M

Ad hoc question in Phase Three

This part of Phase Three attempted to incorporate students' prompted problem-solving attempts. All students were given prompts except those who solved the problem or utilized the full allotted time. The question addressed was: *Did students in each attribution group gain equally from the prompts they received?* A multivariate analysis of variance was carried out with attribution group as the independent variable and the dependent variables as follows: problem-solving progress, understanding, analysis, exploration, verification, planning, and cognitive understanding. Table 15 presents the means and standard deviations across the two trials of problem solving (analysis and planning are not show in Table 15 since there were very low occurrences of these activities). The means representing Phase Three include the scores from students who did and who did not make a second attempt at the problem. There were no significant differences across the three attribution groups. It seems that including in the analysis students who received varying degrees of social support did not result in differences across the attribution groups. Group assignment then did not dictate the gains that would be made in metacognition and problem solving after prompting.

Table 15

Means and standard deviations of cognitive/metacognitive and problem-solving performance for each group at Phase Two and Phase Three

	Phase Two		Phase Three	
	M	sd	M	sd
Understanding				
Unknown	2.1	1.2	2.3	0.9
Effort	2.0	1.0	2.2	1.0
Strategy	1.6	1.5	---	---
Stra-Eff	1.8	2.0	3.0	1.9
Exploring				
Unknown	2.7	1.5	3.4	1.4
Effort	1.6	1.5	2.5	1.8
Strategy	4.0	2.2	---	---
Stra-Eff	2.0	1.9	4.0	0.7
Verifying				
Unknown	0.7	1.3	0.9	1.4
Effort	0.3	0.5	1.0	1.7
Strategy	0.8	1.3	---	---
Stra-Eff	0.0	0.0	1.6	2.0
TotalMeta				
Unknown	6.3	1.4	7.6	2.0
Effort	4.4	2.1	6.7	3.0
Strategy	7.6	4.7	---	---
Stra-Eff	4.4	4.4	10.0	1.2
ProblemSolving				
Unknown	2.1	1.0	2.4	0.8
Effort	1.5	0.7	2.5	1.2
Strategy	3.6	1.7	---	---
Stra-Eff	1.8	1.1	3.2	1.1

Note: Strategy-only group did not make second attempt.

APPENDIX N

Inter-correlations among Attribution and Metacognitive Subscales, Problem-Solving Progress, Metacognitive Activities, and COOP scores

(n=30)	Feff	Seff	Fstra	Sstra	Funk	Sunk	Meta
Feff	x						
Seff	.507*	x					
Fstra	.032	.335	x				
Sstra	.046	.201	.415	x			
Funk	-.245	-.344	-.055	-.158	x		
Sunk	-.612**	-.339	-.235	-.596**	.331	x	
Meta	.241	.447*	.258	.457*	-.289	-.450*	x
PS	.356	.429*	.099	-.249	.049	.079	.111
Und	.031	.194	.087	.337	-.031	-.215	-.045
Ana	.273	.326	.199	-.018	-.220	-.059	.299
Exp	.353	.307	.135	-.161	-.201	-.054	-.021
Ver	.094	-.186	.163	-.116	.062	.139	-.228
Plan	-.168	-.124	-.097	.185	.298	.152	-.068
Ucog	.039	.174	.178	-.007	-.006	.060	-.092
TotM	.318	.303	.221	.042	-.137	-.074	-.006

(n=30)	PS	Und	Ana	Exp	Ver	Plan	Ucog
PS	x						
Und	.047	x					
Ana	.434*	.029	x				
Exp	.731**	.245	.383	x			
Ver	.166	-.170	.020	.019	x		
Plan	.078	.012	-.132	-.324	.266	x	
Ucog	.568**	.429*	.164	.651**	-.056	.158	x
TotM	.675**	.534*	.581**	.781**	.302	.034	.642**

(n=24)	Feff	Seff	Fstra	Sstra	Funk	Sunk	Meta
COOP	.076	-.242	-.119	-.465	-.070	.177	-.378

	PS	Und	Ana	Exp	Ver	Plan	Ucog	TotM
COOP	.161	.054	.279	.393	.164	-.051	.301	.407

Feff=failure-effort; Seff=success-effort; Fstra=failure-strategy; Sstra=success-strategy; Funk=failure-unknown; Sunk =success-unknown; Meta=metacognitive; PS=problem-solving progress; Und=understanding; Ana=analyzing; Exp=exploring; Ver=verifying; Plan=planning/implementing; Ucog=cognitive understanding; TotM=total metacognitive scores.
* $p < .01$; ** $p < .001$

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