ENHANCING SELF-REGULATED LEARNING ON A NOVEL MATHEMATICAL TASK THROUGH MODELING AND FEEDBACK

By

ADAM R. MOYLAN

A dissertation submitted to the Graduate Faculty in Educational Psychology

in partial fulfillment of the requirements for the degree of Doctor of Philosophy

The City University of New York

2009

© 2009

ADAM R. MOYLAN

All Rights Reserved

This manuscript has been read and accepted for the Graduate Faculty in Educational Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

Barry J. Zimmerman, Ph.D.

____

______________ ______________________________________

Date Chair of Examining Committee

Mary Kopala, Ph.D.

____

______________ ______________________________________

Date Executive Officer

Peggy Chen, Ph.D.

____

Bert Flugman, Ph.D.

____

____

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

ABSTRACT

ENHANCING SELF-REGULATED LEARNING ON A NOVEL MATHEMATICAL TASK THROUGH MODELING AND FEEDBACK

by

Adam R. Moylan

Advisor: Professor Barry J. Zimmerman

The power of feedback has been widely acclaimed in research on learning and motivation. However, in educational practice, feedback has typically been conceptualized as an outcome of learning efforts, and not enough attention has been given to its self-reflective role—as a beginning point in cyclical self-regulatory efforts to understand, motivate, and improve one's efforts to learn. This experimental study investigated the influence of various forms of feedback on college students' strategic efforts to learn to solve complex math problems.

Participants were assigned randomly to one of five conditions: 1) control, 2) strategy instruction, 3) strategy instruction plus summative feedback, 4) strategy instruction, summative feedback, and formative feedback, and 5) strategy instruction, summative feedback, formative feedback, and adaptive feedback. *Summative feedback* indicated whether a solution was correct or incorrect, while *formative feedback* involved an indication of the sources of errors, and a*daptive feedback* referred to the student's application of feedback to correct errors plus the experimenter's indication of accuracy

on adjustments made by the student. Students attempted to solve multiple examples of a novel mathematic task during an instruction phase, learning phase, and posttest phase.

The results showed a positive linear trend between increasing levels of elaborative feedback students received and their performance accuracy. In addition, there was a positive linear trend for increased elaborative feedback and strategy adaptation after making errors. Thus, the optimal level of feedback during learning involved information about the source of errors accompanied by self-reflective practice in making strategic adaptations. Progressively elaborative feedback also had additive effects on the important self-reflection phase processes of self-evaluation and self-satisfaction. As hypothesized, self-efficacy predicted performance accuracy and strategy adaptation, as well as self-evaluation and self-satisfaction. Understanding about contexts that help students' to adaptively use feedback to self-regulate has significant implications for classroom assessment that directly fosters learning.

ACKNOWLEDGEMENTS

There are numerous individuals who made this dissertation possible. A very special thank you goes to Dr. Barry Zimmerman, my advisor, from whom I have learned so much throughout the dissertation process, within the classroom, and in many other contexts. These experiences will continue to have a profound impact on me professionally and personally. Another special thank you goes to Dr. John Hudesman, whom has also been a tremendous mentor and support to me since I began my doctoral studies.

Thank you to my committee members, Dr. Bert Flugman, Dr. Peggy Chen, and Dr. Shirley Feldmann, whom have shared their time with me and provided their valuable input. Much appreciation goes to all of the members of the Self-Regulated Learning team both past and present whom have been instrumental in my success. I would also like to express my gratitude to Dr. Carol Tittle and Dr. David Rindskopf for your support and all that you have taught me over the years.

Finally, thank you to my family: my mother, Charlene Weech, David Weech, my brother Simon Moylan, and Odie Moylan, who gave me loving support from day one. Thank you to the rest of my extended family and dear friends for your love and giving me respite from my studies. Last, but not least, thank you to my wife, Aarty Joshi, whose encouragement and support began before this journey and continued until its completion.

In loving and proud memory, I dedicate this dissertation to my father, Thomas Moylan.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION 1

Classroom Assessment Practice 5
Feedback and Self-Regulation 10
Present Study 14

CHAPTER 2 LITERATURE REVIEW 16

Importance of Feedback in Learning 16
Models of Feedback 19
Feedback and Self-Regulation 24
Forethought Phase 26
Performance Control Phase 34
Self-Reflection Phase 34
Development of Academic Self-Regulation 39
Modeling 39
Feedback 41
Final Comments 47

CHAPTER 3 METHODOLOGY AND PROCEDURES 48

Sample 48
Task Materials 49
Design and Procedures 50
Instruction phase 53
Learning phase 54
Posttest phase 54
Measures 55
Hypotheses 59

CHAPTER 4 RESULTS 60

Preliminary Analyses 60
Math Performance 61
Performance Accuracy 61
Math Strategy Adaptation 64
Self-Judgments 66
Self-Evaluation 66
Causal Attributions 69
Self-Reactions 71
Self-Satisfaction 71
Adaptive Inferences 72
Anxiety 73
Self-Motivation Beliefs 73
Self-Efficacy 73
Task Interest 74
Goal Orientation 74
Calibration 75
Self-Efficacy Bias 75

Self-Evaluation Bias......*76*
Correlations Among Dependent Variables......77

CHAPTER 5 DISCUSSION......79

Math Performance......80
Strategy Adaptation......81
Self-Reflection......81
Forethought......83
Limitations and Recommendations for Further Research......84
Educational Implications......85

APPENDIX A......90

APPENDIX B......91

APPENDIX C......92

APPENDIX D......93

APPENDIX E......94

APPENDIX F......97

REFERENCES......126

LIST OF TABLES

Table 2.1 Abridged List of Shute's (2008) Feedback Elaboration Levels 18

Table 2.2 Developmental Level Model of Self-Regulation (Zimmerman, 2002b) 39

Table 3.1 Experimental and Control Conditions 52

Table 4.1 Posttest Means (and Standard Deviations) for Dependent Measures 62

Table 4.2 Chi-Square Analysis of Adaptation Between Experimental and Control Groups 65

Table 4.3 Partitioning the Chi Square: Strategy Adaptation.. 66

Table 4.4 Analysis of Variance for Intervention Effects on Self-Regulatory Measures .. 69

Table 4.5 Percentage of Attributions for Experimental and Control Groups after Missing Target Answer.. 70

Table 4.6 Means and Standard Deviations of Calibration Bias of Self-Efficacy and Self-Evaluation Judgments 75

Table 4.7 Correlations Among Dependent Variables 78

LIST OF FIGURES

Figure 1.1 Triadic Forms of Self-Regulation (Zimmerman, 1989) 11

Figure 1.2 Social Cognitive Model of Self-Regulation (Zimmerman & Campillo, 2003)13

Figure 4.1 Posttest Performance Accuracy for Experimental and Control Groups.......... 63

Figure 4.2 Bar Graph of Mean SRL Processes by Experimental and Control Conditions68

Figure 4.3 Adaptive Inference and Subsequent Performance Accuracy 73

Figure 4.4 Mean Calibration Bias of Self-Efficacy and Self-Evaluation Judgments by Condition... 76

CHAPTER 1 INTRODUCTION

Feedback has a vital influence on learning and is a fundamental mechanism of the teacher-student transaction. Evidence about the importance of feedback to learning comes from varied areas of research, including research on transfer, adaptive expertise, and child development (Bransford, Brown, & Cocking, 2000). Feedback is defined commonly as corrective information that helps learners to close gaps between current performance or understanding and learning goals (Hattie & Timperley, 2007; Ramaprasad, 1983). Learners have to interpret and act upon feedback—it is not enough for teachers or other external sources merely to provide it. Hattie and Jaeger (1998, p. 10) put it aptly by saying, "Reducing class size, prescribing more homework, introducing more computers, etc. merely provides increased opportunities for appropriate challenging goals and more feedback to occur—it does not guarantee that they will occur". How can we help students to become strategic *users* of academic feedback to further their learning? A more elaborate analysis of feedback is required to explain why desirable feedback effects on motivation and learning do and do not occur (Kluger & DeNisi, 1996).

Extensive reviews of research on learning have shown that the provision of frequent, process-related feedback while learning is occurring have been among the most powerful of educational interventions (Bangert-Drowns, Kulik, & Kulik, 1991; Black & Wiliam, 1998; Crooks, 1988; Fuchs & Fuchs, 1986; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Natriello, 1987; Shute, 2008). Assessment practices that exemplify research findings on effective feedback are designed to provide feedback to *enhance* learning rather than just measure what has been learned (Sadler, 1998). These practices have been described in various ways, including *formative assessment* (Bloom, 1969; Bloom, Hastings, & Madaus, 1971), *educative assessment* (Wiggins, 1998), or

assessment for learning (Broadfoot, Daugherty, Gardner, Gipps, Harlen, James, et al., 1999; Stiggins, 2002; Sutton, 1995). Black and Wiliam (1998) defined *formative assessment* as "all those activities undertaken by teachers and/or by students which provide information to be used as feedback to modify the teaching and learning activities in which they engage" (pp. 7-8). Formative assessment is informative—it focuses on furthering the learning process. Assessment in the service of learning functions as a catalyst for students' beliefs and judgments about their goals, their progress towards meeting those goals, and what to do next in the learning process.

The use of the term 'formative' in the context of assessment was borrowed by Bloom (1968) from Scriven's (1967) distinction between formative and summative evaluation. Formative evaluation refers to evaluative efforts that occur *during* the process of implementing a program or making organizational improvements. Evaluators share feedback from formative evaluation with stakeholders to make adjustments in programmatic or organizational efforts. In contrast, summative evaluation refers to evaluation efforts that assess the outcomes of a program or organization *after* program implementation or organizational change. The term evaluation tends to be used in the context of systems, programs, and organizations. A distinction then can be made when using the term assessment, so that it refers more often to classroom, small group, and individual learning contexts.

During the civil rights movement in the United States, achievement disparities began to rise to the forefront of educational concerns as more Americans came to recognize the need to help *all* students reach their fullest potential. Backed by extensive, cross-national investigations of effective teaching practices, Benjamin Bloom and

colleagues (Bloom, 1969; Bloom, 1985; Bloom, Hastings, Madaus, 1971; Bloom, Madaus, Hastings, 1981) argued that teachers needed to differentiate and diversify instruction to address the wide variance in students' prior achievement and current learning needs. To accomplish this goal, teachers had to integrate assessment with instruction. Specifically, teachers had to do three things—view assessment as feedback sources, support the corrective process, and provide additional assessment opportunities for progress feedback and motivation-enhancing experiences of success (Guskey, 2007). Essentially, this became the core of Bloom's (1968) mastery learning approach to teaching and learning.

At the heart of Bloom's approach was the assumption that mistakes are integral to learning. In fact, less-than optimal performance is held desirable because it sparks further learning (Wiggins, 1998). A learning environment that views mistakes as a necessary part of learning relates intimately to a continuous process of formative assessment where feedback is used in an ongoing manner for adaptation.

The theoretical contrast to formative assessment is *summative assessment*, which is assessment concerned with verifying achievement *after* learning has occurred. Summative assessment, in general, involves evaluating or judging what learning has occurred or measuring performance skills acquired. Ironically, assessment measures or practices classified as summative do not typically base appraisals of learning by amassing and summarizing information about the progression of learning, but tend to rely on a single test or other assignment as an indication of achievement. Certainly, summative assessment plays a critical role in determining the potential of individuals and influences their academic trajectories—and thus are formative in a sense. For example, summative

assessments are used in decisions about what courses of study a student is allowed to take, what schools one can enroll in, and influence beliefs about what a learner is capable of achieving. In fact, the distinction between formative and summative is perhaps best viewed in relation to what *function* the assessment serves rather than characterizing some inherent quality of the assessment itself (Wiliam, 2007). Thus, a particular assessment could have different functions for different students and teachers.

The concepts of feedback and assessment dynamically intertwine. Some researchers argue for a separation between feedback and summative assessment (e.g. Crooks, 1988). The crux of the argument being that feedback inherently involves feeding information back for self-correction, and by definition, summative assessment is used solely to measure what level of learning or performance has been attained, not to further enhance it. Others would argue that assessment always provides some form of feedback about gaps between performance and criterion levels. The view taken in this proposal follows the definition of feedback put forth by Ramprasad (1983): “Feedback is information about the gap between actual level and the reference level of a system parameter which is used to alter the gap in some way” (p. 4). Sadler (1989) and others (e.g. Wiliam, 2007) emphasize that information about a gap has to be *used* to be considered feedback. Therefore, feedback is most closely connected with formative assessment, which is engineered to enhance learning. In practice, formative assessment is applied by many to the *intention* or *capability* to help students make corrective action. For the purposes of this proposal, *adaptive feedback* is used to make a distinction between the intention for feedback to be formative and the process of actually using feedback to make adaptations in learning and performance methods.

Summative assessment (or feedback) represents the most basic form of feedback and is often described as outcome feedback or the classical *knowledge of results* (Butler & Winne, 1995). This information simply indicates if a response is correct or not to make a judgment about past performance. Summative feedback does not really 'feed-forward' information that helps a learner self-regulate, or at least not explicitly. Outcome information alone does not inform the learner's decisions on how to make adjustments (Wiliam & Leahy, 2007). The need to make a change can be expressed implicitly or explicitly, but *what* to change or *how* to change is not stated explicitly or implicitly. Behavior change alone after externally given feedback does not make it formative.

Sometimes, summative feedback may suffice as a cue for learners to adjust successfully their efforts. In this type of situation, the learner relies on self-generated feedback—by perhaps adaptive help seeking (Newman, 2007) or self-recording targeted components of performance—to identify the reasons for errors and the ways to adjust their methods. When both summative *and* formative feedback is available, it is likely to have a positive influence as a learner self-reflects on past performance. In such a situation, the learner judges and reacts to outcome information in comparison with criteria for satisfactory goal progress, and adapt their methods based on formative feedback that specifies where adjustments are needed to correct gaps between actual and desired performance.

Classroom Assessment Practice

There is extensive history showing educational stakeholders being concerned primarily with summative assessments, as well as contemporary evidence associated with expanding external accountability efforts, large-scaled standardized instruments, and the

No Child Left Behind Act of 2001 (U.S. Department of Education, 2002). In light of these larger-scaled purposes for assessment, Wiliam (2007) has delineated a third function of assessment, beyond formative or summative, to be *evaluative*. High-stakes testing efforts fall within the evaluative function because they are used to evaluate the quality of academic programs and institutions. The three purposes or functions of assessment—formative, summative, and evaluative—operate at different levels of hierarchy or specificity. Certainly, in educational practice, the distinctions between formative, summative, or evaluative assessment can blur. Some researchers have argued that the same assessment activity or instrument cannot adequately serve dual purposes (Torrance, 1993). However, in actual practice it has been found that teachers who are making the change of emphasizing or introducing formative assessment into their classrooms have found it necessary to use formative strategies to prepare for summative assessments (Black, Harrison, Lee, Marshall, & Wiliam, 2003; for more on using assessment for formative and summative purposes see Harlen, 2006).

Contrary to widely accepted principles of learning as an ongoing, iterative process, educational approaches often compartmentalize instruction into brief, discrete lessons or learning units that are rather rigid in pacing and lack sufficient continuity from one topic to the next (Bransford, Brown, & Cocking, 2000; Zimmerman, Bonner, & Kovach, 1996). In such contexts, students tend to face assessments that occur only at the end of each learning unit. This can make it difficult for students to utilize feedback in recursive attempts to gain mastery. These assessments are more summative than formative—tending not to provide feedback to the teacher or student on how to make effective adjustments for optimal learning. Instead, end-of-the-unit assessments tend to

emphasize retrieval rather than learning—meaning that they are designed to evaluate learning rather than foster learning (Sternberg & Williams, 1998). Compartmentalized instruction does not provide the flexibility or multiple opportunities for students to adjust learning methods as they seek mastery.

Considering that the vast majority of days of the school year have to be devoted to learning, teachers and students require feedback that furthers academic attainment on a daily basis (Stiggins, 2007). In this manner, formative assessment is critical to motivating and enhancing learning. Formative assessment provides formative feedback—informing a learner how to adapt their methods in their goal pursuits. Ongoing, formative feedback helps to make connections between prior knowledge and performance competencies with the present. If the function of assessment shifts to assessment as learning activity, assessment becomes integrated with instruction, as has been exemplified in mastery learning and curriculum-based measurement approaches (Fuchs, 1995; Zimmerman & DiBenedetto, 2008). Mastery learning takes this approach by providing a progressive, hierarchical sequence of instructional topics with flexible pacing to better support differences in learners' development of mastery (Bloom, 1968; 1985). As has been advocated by Covington (2000), classrooms require "new rules of engagement that recognize students' efforts for self-improvement, for task diligence, and for making progress as well as for correcting their own learning errors—yardsticks of accomplishment that are open to all, irrespective of ability, status, or past experience" (p. 189).

Of course, as revealed by research on formative assessment studies (Black & Wiliam, 1998a), not all formative assessment practices have the same positive effects on

learning. One reason that general classroom assessment methods are lacking, for both students and teachers, is that academic feedback is predominately in the form of grades and assessments are created largely just for this purpose (Brookhart, 1994). Grading practices alone seldom provide adaptive help to students, and can often lead to counterproductive, defensive reactions. Repeated low grades are likely to reinforce students' notions of poor ability or encourage them to attribute causes of graded outcomes to external sources. As early as Thorndike (1913), the negative effects of grades were a concern in education. Thorndike explained that grades could be an impediment to learning by lacking specificity and emphasizing comparative judgments relative to others. This is likely to be the case particularly with the use of normative grades, because these grades indicate proficiency in relation to the performance of others rather than in relation to specific aspects of the task. In contemporary classrooms, an over-reliance on external accountability assessments and tests of recall generate minimal feedback (Hattie & Timperley, 2007; Zimmerman & DiBenedetto, 2008). By design, such assessments do not integrate well, if at all, into instruction and learning processes. In many contexts, grades or scores as sources of academic feedback alone do not provide the elaboration or focus that is needed to be interpreted and put to action by teachers and students.

Recently, there has been a growing emphasis on *students as users of the assessment process*. Advocates of assessment for learning, such as Stiggins (e.g. 2007), argue for a greater focus on the students' interpretations and actions because they wield much greater influence on their learning success than do others. Ultimately, whether a particular assessment activity is *formative* can be judged by whether students respond to

the assessment feedback by effectively making improvements in their learning efforts (Black & Wiliam, 1998b; Wiliam, 2007). Thus, validity issues are pertinent to a discussion of formative assessment (Stobart, 2007). Evidence of the desired effects of assessment supports consequential validity arguments (Messick, 1989)—as well does evidence of the absence of undesirable effects.

Without guidance from teachers or peers or structured activities, many students who perform poorly on an assessment will not make sufficient effort to identify why they made errors and what they could do differently to be successful in further learning attempts. Such students miss the opportunity to use feedback for self-correction. Of course, academic grades are the predominate form of feedback, but marks alone provide little information about how to go about making changes. Therefore, in these contexts, students naturally play a passive role as the teacher shifts to a new instructional focus and the students await their next academic grade (Bransford, Brown, & Cocking, 2000). Considering that the interpretations of assessment results by teachers and students mediate the intended effects on instructional and learning change (Tittle, 1994), it is surprising that most teachers give rare attention to creating opportunities for students to self-reflect about their learning (McCaslin & Good, 1996). Recall that Bloom's (1968, 1969) original contention was that providing feedback through assessment was not enough—teachers also needed to provide quality corrective instruction and subsequent assessment opportunities to measure learning growth. In this view, quality feedback is frequent, focused on process and small steps, and is in a form that is usable—that is, it can be enacted into changed actions (Brookhart, 2007).

Feedback and Self-Regulation

Despite the expansive body of research on feedback spanning the past century, there is insufficient clarity about the processes that influence or mediate the effectiveness of feedback. As a result, important empirical work in this area continues, and researchers continue to conduct extensive reviews and develop models in attempts to improve understanding of disparate findings (e.g. Hattie and Timperley, 2007; Shute, 2008).

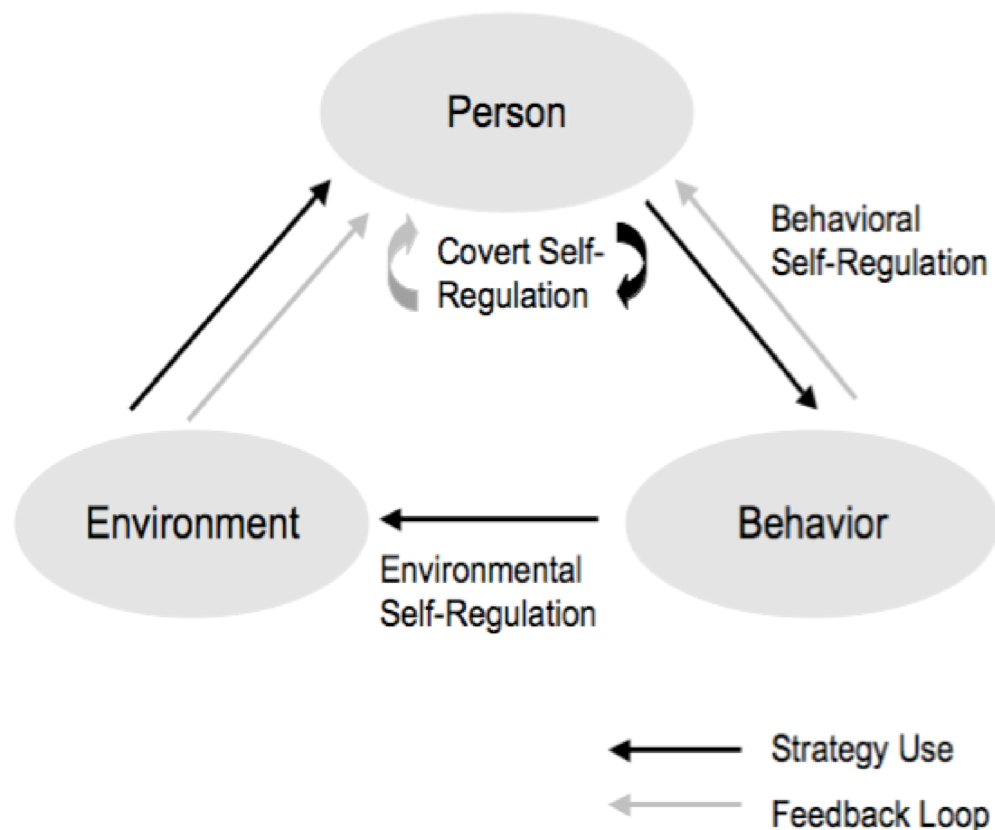
The central importance of feedback is on informing successive adaptations or adjustments that result in closer approximations to desired goals. Social cognitive theorists explain this process of adaptation through self-regulation (Bandura, 1986; 1997). At its core, self-regulation is a feedback loop. Self-regulated learning (SRL) involves the cyclical use of feedback to make strategic adjustments in learning activities (Schunk, 2001). Self-regulatory feedback can come from external, social sources such as the teachers' marks on an assignment or test, as well as from more internal or self sources such as through self-testing. Both social feedback and self feedback are judged to be important to the development of self-regulatory feedback (Zimmerman, 2004).

The belief that self-regulation is important to education is widespread. Bandura wrote, "A fundamental goal of education is to equip students with self-regulatory capabilities that enable them to educate themselves. Self-directedness not only contributes to success in formal instruction, but also promotes lifelong learning" (p. 174). Arguably, a fuller consideration of both the multifaceted influence of feedback in learning and how to optimize it requires a broader view that encompasses feedback within a self-regulatory framework (Butler & Winne, 1995). A self-regulatory perspective on formative assessment underscores the *students' adaptive use of academic*

feedback to self-regulate learning as an alternative to the usual focus on teachers' use of feedback.

Bandura's (1986) social cognitive theory perceives self-regulation as involving triadic reciprocity between personal, behavioral, and environmental factors. A model of the triadic forms of self-regulation is depicted in Figure 1.1 (Zimmerman, 1989). To develop expertise, a learner must deliberately self-regulate their covert personal processes, their behavioral performance, and environmental contexts (Zimmerman, 2006). Effective self-regulated learners use feedback from personal, behavioral, and environmental sources to adapt their learning strategies, initiate the use of strategies, self-monitor and adjust based on situational features, and maintain motivation.

Figure 1.1
Triadic Forms of Self-Regulation (Zimmerman, 1989)

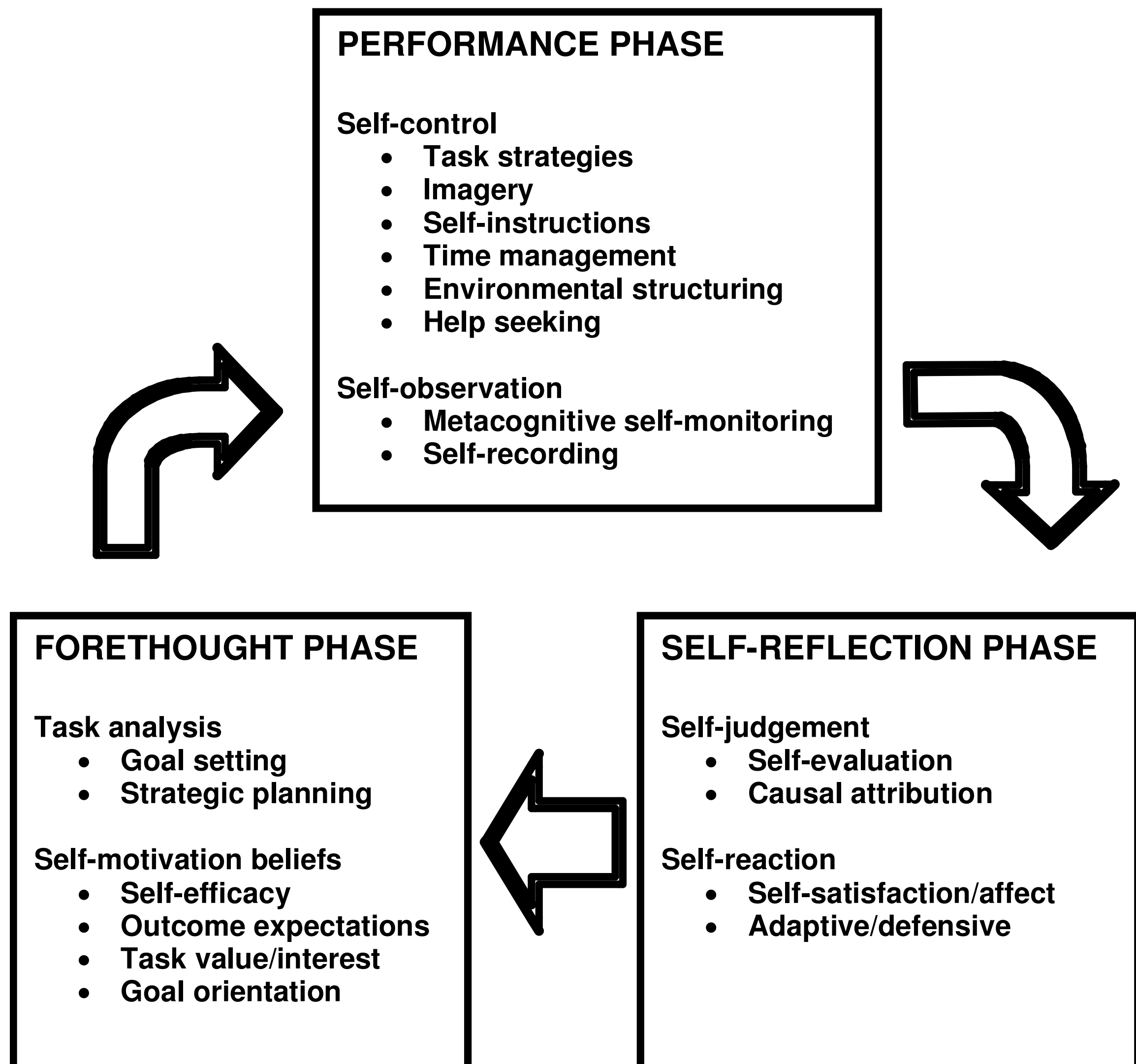


cyclical phases consist of multiple self-regulatory processes and motivational beliefs. Feedback plays an important role in each phase. Effective self-regulators engage in proactive forethought and performance control phases, as well as reactive self-reflective processes to make cyclical self-adjustments (Zimmerman, 2006). The forethought phase precedes learning or performance. This phase involves task analysis processes such as goal setting and strategy selection, as well as self-motivational beliefs such as self-efficacy beliefs and outcome expectancies. The performance phase, which occurs during learning or performance, involves self-control such as task strategies, and self-observation processes such as metacognitive self-monitoring. Self-reflection phase processes involve students' responses to learning or performance, and include self-evaluation and attribution self-judgments and self-satisfaction/dissatisfaction and adaptive/defensive self-reactions.

A social-cognitive model of SRL can be a particularly helpful framework for understanding the complexity of learning because it involves not just cognitive or metacognitive regulation, but also the regulation of motivation and affect, behavior, and context (Zimmerman & Kitsantas, 2005; Zimmerman & Moylan, 2009). In addition, social cognitive theorists include explanations about the social sources of self-regulatory competence, rather than focusing primarily on internal or cognitive sources (Schunk & Zimmerman, 1997). In this view, the development of self-regulatory competence from social origins involves four levels: observational, emulative, self-controlled, and self-regulated. The observational and emulative levels highlight the social sources for development of self-regulatory skills. Observational learning refers to the acquisition of a

new pattern of behavior while attending to a model (Pintrich & Schunk, 2002). Such behavior is learned observationally if it would not have occurred otherwise.

Figure 1.2
Social Cognitive Model of Self-Regulation (Zimmerman & Campillo, 2003)



Present Study

A self-regulated perspective on formative assessment emphasizes the students' *adaptive use* of assessment feedback to regulate their learning. From a social cognitive perspective, adaptation refers to how self-regulated learners' make strategic adjustments in response to feedback to further progress towards their goals. According to Zimmerman's model of self-regulated learning (2000), feedback is mediated partially through the self-reflection processes of self-judgments and self-reactions. Post-performance *self-evaluative judgments* that a learner makes in response to feedback mediate the making of adjustments. A learner decides whether their present state meets their goal criteria. Learners also experience self-satisfaction or dissatisfaction depending on their outcomes and desired goals. The inferences learners make to feedback, according to Zimmerman, can be adaptive or defensive. It is critical that feedback from an external source leads to adaptive beliefs and actions by the learner rather than defensive beliefs and actions, which can involve withdrawing from or lowering one's goals, or complacency with one's current methods despite a lack of progress achieved. Self-reflection phase processes are important to understanding both the successes and failures to use feedback in ways that enhance motivation and learning.

There is a need to expand upon the existing body of research on feedback to focus on improving our understanding about how self-reflection processes, as well as forethought and performance control phase processes, are involved in learners' self-regulated use of academic feedback. The present research uses Zimmerman's (2000) social cognitive model of academic self-regulation to investigate experimentally the use of different forms of feedback in a self-enhancing, cyclical process. An emphasis is

placed on considering the explanatory contribution of the self-reflective processes of self-regulation involved in learners' responses to external feedback on performance. Specifically, the aim is to test whether performance and self-reflective processes involved in learning a novel mathematical task can be enhanced additively through strategy instruction and the provision of summative feedback, formative feedback, and adaptive feedback. The study focuses on the first two levels of a social cognitive model of how self-regulatory competence develops—the observation and emulation levels (Schunk & Zimmerman, 1997). Modeling of strategy use relates to the observational level, and the provision of feedback by the experimenter during practice relates to the emulation level. Furthermore, this study seeks to shed light on the issue of calibration of self-efficacy and self-evaluation judgments to actual performance in the context of learning a new problem-solving task in mathematics. Overall, this research may provide some insight towards greater understanding of feedback-related instruction and assessment strategies that can enhance learners' academic self-regulation.

CHAPTER 2 LITERATURE REVIEW

Importance of Feedback in Learning

The father of educational psychology, Edward L. Thorndike (1913) attested to the critical role of feedback in learning with his *law of effect*. Essentially, the law of effect refers to the empirical findings that the strength of a connection between a situation and response, with other things being equal, will increase if it leads to satisfaction, while dissatisfaction with results will likely diminish the connection. The behavioral approach of Thorndike was later expanded upon by cognitive approaches. Generally, cognitive scientists described learners as actively pursuing information about their performance—both behavioral and cognitive information. One cognitive theorist, Kulhavy (1977) described the importance of feedback to be fundamentally about helping learners to correct errors. More than just seeking to know whether right or wrong, humans actively seek feedback that can help them make adjustments.

There is a multiplicity of reviews of educational and psychological research reporting diverse findings regarding feedback, including positive, null, and negative effects on learning and motivation (Azevedo & Bernard, 1995; Balzer, Doherty, & O'Connor, 1989; Bangert-Drowns, Kulik, & Kulik, 1991; Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Black & Wiliam, 1998; Hattie & Timperley, 2007 Kluger & DeNisi, 1996; Natriello, 1987; Shute, 2008). Mixed research findings about optimal forms of feedback suggest there is no one particular recipe for feedback that is universally effective, and researchers will no doubt continue to investigate feedback-related interventions. However, some feedback processes or dimensions do seem generally effective (Mason & Bruning, 2001). Some key dimensions of feedback concern when to give feedback, how much feedback to give, and how to deliver the feedback.

The *timing* of feedback has been found to influence its effectiveness. In general, immediate feedback after performance is found to be more valuable than delayed feedback. According to Kulik and Kulik (1988), evidence of greater intervention effects on learning for delayed feedback in comparison to immediate feedback tended to be the result of basic memory-related tasks. However, interventions that involved more complex, conceptual understanding or problem solving displayed greater learning gains when feedback was presented immediately after response. Associated closely with the timing of feedback is the frequency of feedback. Generally, frequent feedback is desirable (Bangert-Drowns, Kulik, & Kulik, 1991). Feedback interventions involving quizzes or tests have shown that several times a week is beneficial to students. In turn, connected closely to the issue of the frequency of feedback is the amount of feedback that is present.

For the purposes of delineating how different types of feedback influence learning, Kulhavy (1977) felt it was warranted to view different forms of feedback along a continuum—from basic right-wrong indices (classic knowledge of results) to more complex forms of feedback. Along the continuum, the information can move beyond an indication of just the correctness of past performance to informing what to do next (i.e. instruction towards further learning). The level of *elaboration* of feedback is an important consideration to the degree of influence feedback has on learning and performance. Yet, merely increasing the elaboration or complexity of information does not necessarily coincide with a parallel increase in learning (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Kulhavy, 1977). Elaborated feedback can include many different types of feedback

that have been investigated in the literature (see Table 1 for description of feedback types derived largely from Shute, 2008).

Table 2.1
Abridged List of Shute's (2008) Feedback Elaboration Levels

Type	Description
1. No feedback	No indication of correctness of performance.
2. Knowledge of results	Refers to an indication of the accuracy of performance such as right or wrong or an accuracy score.
3. Correct response	The correct response or performance is given.
4. Try again	Knowledge of results is given, plus another performance attempt.
5. Source of errors	The location of errors is shown, but the correct performance is not.
6. Elaborated	
6a. Cues	Learner is prompted about how to make changes.
6b. Bugs or misconceptions	Error analysis is provided such as what went wrong and why.
6c. Informative tutoring (Narciss & Huth, 2004)	Learner is provided with knowledge of results, source of errors, and strategic cues about next steps.

Generally, research suggests that feedback should be timely, should focus on progress, and should be specific and differentiated to needs of the learner (Crook, 1988). These aspects of feedback naturally coincide with research on goal setting (Locke & Latham, 1990) and are discussed further in the chapter. Other variables that influence the

effectiveness of feedback on learning include the students' motivational beliefs, perceptions, prior achievement, existing knowledge, and the characteristics and demands of the task (Shute, 2008). Some of these other variables are presented in further sections of this chapter. Now, several models of feedback that arose from classical feedback studies as well as contemporary views of feedback are summarized briefly.

Models of Feedback

A number of systematic reviews of research on feedback have been used in initial attempts to formulate models of the multidimensional influence of feedback in learning processes (e.g. Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Kulhavy & Stock, 1989). Based upon a review of feedback studies focused on the test-feedback-retest paradigm, Kulhavy and Stock (1989) presented a model of instructional feedback that identified response certitude as a mediating variable of the amount of effort exerted after receiving feedback and the probability of self-correction. *Response certitude* refers to self-judgment of confidence in the correctness of a response, and in their paradigm, it was assessed immediately after the initial test and before outcome feedback was provided to the student. *Discrepancy* is the gap between response certitude or confidence and knowledge of results feedback. For example, if a learner is highly confident in their performance but they receive error feedback, discrepancy arises. Kulhavy and Stock (1989) hypothesized that the greater the discrepancy, the greater the motivation to self-correct and the greater the probability of self-correction on retest. This hypothesis is problematic because it focuses on the self-reactive processes of learners while disregarding the proactive control processes.

According to Bandura (1997), both proactive control and reactive control processes are necessary for self-motivation.

Subsequent research has shown that students' perceived discrepancy is influenced by their goals, thus mediating their effort to reflect on feedback and the probability of successful adjustment on subsequent responses. The active self-regulation of learners was made evident in a study by Schutz (1993) that assessed students' effort to learn a computer programming language by measuring the frequency of requests for feedback. Schutz found that learners with higher performance goals requested more feedback. Interestingly, the feedback in this investigation involved more than mere outcome feedback. Instead, feedback was more closely related to specific components of the learning process. Learners engaged in metacognitive self-monitoring by comparing their pre- and post-performance confidence judgments with their goals and performance to assess the accuracy of the self-judgments. That is, learners were self-monitoring their *calibration* (Butler & Winne, 1995). Unexpected inaccuracies can cue self-regulatory adjustments (Carver & Scheier, 1990). However, discrepancy reduction or striving for equilibrium is not merely a reactive (i.e., automatic) process (Bandura, 1986; 1997). Learners are also proactive regulators of their motivation. Bandura (2008) had the following to say regarding self-reflecting about the accuracy of one's thoughts:

> Effective functioning requires reliable ways of distinguishing between accurate and faulty thinking. In verifying the adequacy of thought by self-reflective means, people generate ideas and act upon them or predict occurrences from them. They then judge from the results the accuracy and functional value of their thinking and try to improve it if necessary (p. 17).

The calibration or congruence of perceived self-efficacy with performance accuracy has been a topic of interest among social cognitive researchers for several decades (Schunk, 1980). Self-regulation research has shown the calibration of learners' self-efficacy beliefs can be improved through the emulative practice of the learner (Zimmerman & Kitsantas, 2002). Balzer, Doherty, and O'Connor (1989) found in their review of outcome feedback versus process-related feedback (described by the authors as *cognitive feedback*) that the latter form of feedback supports metacognitive monitoring. Some recent evidence in self-regulated learning research suggests that learners provided with frequent, timely feedback about their mathematics learning in combination with systematic activities to use the feedback adaptively, exhibit not only greater achievement, but also enhanced calibration of their self-appraisals (Zimmerman, Moylan, Hudesman, White, & Flugman, 2008; Zimmerman & Moylan, 2009).

After an extensive, focused review of feedback literature on 'test-like' events, Bangert-Drowns, Kulik, Kulik, & Morgan (1991) arrived at a five-stage model of feedback's effects on learning: current state, search/retrieval, response, evaluation, and adjustment. This feedback cycle model was an important contribution to scholarship on feedback because it emphasized the critical importance of self-reflection (the authors used the term 'mindfulness') involved in the learner's use of feedback. The studies reviewed by these authors tended to show only small effects on learning. The weak effects were attributed largely to learners not attending mindfully to the feedback they received.

Feedback models, or theories of learning that integrate feedback as a component (e.g., control theory, Carver & Scheier, 1981; and goal-setting theory, Locke & Latham,

1990), have historically had limitations in terms of explaining the varying effects of feedback reported in the literature. In their often-cited review, Kluger and DeNisi (1996) attempted to integrate the diverse theoretical areas of research on feedback with their feedback intervention theory (FIT). To understand feedback processes, the authors relied heavily upon explanations involving goal setting and standards (from goal-setting theory), as well as the role of attention resources and direction (from control theory).

Several recent reviews of feedback-related research (Hattie & Timperley, 2007; Narciss & Huth, 2004; Shute, 2008) have centered specifically on formative feedback. Recently, Hattie and Timperley (2007) presented a model of feedback that views the effectiveness of feedback on learning depends on both the quality of information and the level to which it is directed. Regarding the quality of information, feedback can address three questions: 1) Where am I going?, 2) How am I doing?, and 3) Where to next? The most effective feedback is thought to integrate all three questions. Feedback about *where a learner is going* in the learning process is information that pertains to goals. Feedback about *how the learner is doing* provides critical progress information in relation to task or performance goals and specific evaluative standards. Feedback that pertains to *"Where to next?"* is suggestive of increasing goal standards in the learning process or higher levels of mastery.

The Hattie and Timperley (2007) feedback model includes four levels at which responses to feedback are believed to work: 1) the task level, 2) the process level, 3) the self-regulation level, and 4) the self-level. Although the conceptual distinctions between these levels are somewhat blurred, an important contrast is made between feedback directed at the self versus tasks, processes, or self-regulation. Feedback directed at the

latter three levels focus on mastery-orientation or task-involvement, giving information that helps the learner make adjustments. In contrast, feedback directed at the self is typically uninformative because it is ego-involved and does not direct attention towards performing the task. For example, praise unrelated to specific behaviors or not made contingent upon a response generally has weak effects. Hattie and Timperley (2007) theorized that: "Learning can be enhanced to the degree that students share the challenging goals of learning, adopt self-assessment and self-evaluation strategies, and develop error detection procedures and heightened self-efficacy to tackle more challenging tasks leading to mastery and understanding of lessons" (p. 103). Their model of feedback highlights the role of the learner's self-regulation and self-beliefs in using feedback, and this is consistent with a social cognitive model of self-regulated learning.

Various models of feedback have been described only briefly here, because they are limited inherently in their explanatory power. In response to the review of formative assessment by Black and Wiliam (1998), Perrenoud (1998) made the following observation:

> This [feedback] no longer seems to me, however, to be the central issue. It would seem more important to concentrate on the theoretical models of learning and its regulation and their implementation. These constitute the real systems of thought and action, in which feedback is only one element. (p. 86)

Self-regulation and social cognitive theory (Bandura, 1986, 1997) provide a powerful framework for understanding the multi-faceted roles of feedback in learning and motivation. The next section of the chapter elaborates on a social cognitive perspective of self-regulated learning.

Feedback and Self-Regulation

At this point, I would like to summarize how feedback is viewed in relation to formative assessment using the following excerpt from Paul Black and colleagues (Black, Harrison, Lee, Marshall, & Wiliam, 2003):

> It is important to emphasize the critical criterion—formative assessment is a process, one in which information about learning is *evoked* and then *used* to modify the teaching and learning activities in which teachers and students are engaged. Insistence on precise criterion does not imply a restricted range of activities. The evidence can be *evoked* in a wide variety of ways, from the puzzled look on a student's face to analysis of that student's response to homework task or a question in a formal test, but to identify this process, on its own, as feedback is a serious misunderstanding, albeit a common one. After all, a thermostat which turned out to do no more than measure and record temperature change would quickly be discarded as useless. Feedback can only serve learning if it involves both *evoking* of evidence and a response to that evidence by *using* it in some way to improve the learning. (p. 122)

Feedback has multidimensional influences on learning, including cognitive effects, motivational and affective effects, and behavioral effects. Unlike models of SRL that primarily focus on cognitive or metacognitive aspects of self-regulation, a social cognitive model places equal emphasis on motivational aspects of self-regulation (Zimmerman & Schunk, 2007) and social aspects (Schunk & Zimmerman, 1997). This is one reason why a social cognitive model of self-regulated learning is germane to understanding the power of feedback. The social cognitive approach is also important

because of it considers the dynamic, reciprocal influences between personal, behavioral, and environmental factors.

Self-regulation is described as an adaptive process (Boekaerts & Corno, 2005; Butler & Winne, 1995; Zimmerman, 2000). The process of using performance feedback to make adaptations in future responses is central to self-regulation. A defining characteristic of what makes humans different from other species is their capacity to be agents of self-directed change (Bandura, 1986; 1997). Self-regulation refers to "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals (Zimmerman, 2000, p. 14). People are not just reactive beings to discrepancy feedback; they are also proactive and aspiring beings (Bandura, 1997). The social cognitive view of SRL goes beyond describing a negative feedback loop entailing automatic motivation to reduce discrepancies. In addition to this reactive nature of SRL, a social cognitive perspective also highlights its proactive nature (Zimmerman, 2000).

Figure 1 shows the three phases of Zimmerman's (2002b) SRL model: forethought, performance, and self-reflection. Within each phase are key subprocesses. The forethought phase involves task analysis processes and self-motivation beliefs. The performance phase includes self-control and self-observation processes. Lastly, the self-reflection phase involves self-judgment and self-reactive processes. The cyclical nature of self-regulation means that the latter processes then influence subsequent forethought efforts. The following sections elaborate on key self-regulatory processes, with particular focus on relations with feedback.

Forethought Phase

The forethought phase refers to learners attempts to accurately assess their prior experience, conduct a task analysis, select strategies that best address their specific challenges and strengths, and set identifiable academic goals. The role of motivational beliefs on learners and the learning process is a key contribution of a social cognitive perspective on SRL. Self-efficacy beliefs and outcome expectancies play key motivational roles in the choice of goals and subsequent effort towards achieving success. The following section describes the forethought phase processes of goal setting, self-efficacy, and goal orientation.

Goal Setting and Feedback

A key process of task analysis is goal setting. Learning involves a complex, intertwined relationship between goals and feedback (Hattie & Timperley, 2007). A combination of challenging goals and performance feedback are found to increase student engagement (Black & Wiliam, 1998). The type of feedback and how it is used by the learner are likely to have discernable effects on the quality of learning and performance (Locke & Latham, 1984). Feedback allows for more accurate monitoring of performance so that adjustments can be made in strategies, goals, or effort (Locke & Latham, 1990). In naturalistic settings, feedback regarding tests may be quite general, as are the goals and criteria for success. Feedback needs to focus on the criteria for successful task performance or goal attainment. For example, a test performance score with a clear connection to a scoring rubric from which to make meaning of the grade is helpful feedback for student and teacher. Test feedback that identifies the source of errors or provides guiding questions can also help students learn from their mistakes.

Not only is goal setting ineffective without feedback, but feedback without goal setting is less effective (Hattie & Jaeger, 1998). Goal-directed behavior is a key motivational construct, which is indispensable for creating successful learning environments. Goals allow for determination of the criteria for a task and standards for self-satisfaction. When there is a specific goal, feedback can be interpreted in a focused manner. Clear goals influence the effectiveness of feedback through the process of self-evaluating the discrepancy between present performance and goals and outcome expectations. Diffuse, vague goals or prematurely outcome-focused, distal goals make it difficult for the learner to assess accurately their performance in relation to desired goals (Zimmerman & Kitsantas, 2005). Proximal goals for successive self-regulatory cycles enable a learner to focus their attention on specific aspects of their performance that they perceive to need improvement. Proximal goals focus on process by providing immediate, detailed information about one's performance. In developing self-regulatory competence, a learner requires attention to the fine pointed details of performance until automaticity is achieved. Once this latter level is attained, the individual can shift attention more towards performance outcomes. However, this higher level of self-regulation is not fixed. When the individual deems necessary, they will return their focus back to process-oriented features. The social cognitive SRL model emphasizes the value of setting both process (proximal) and outcome (distal) goals.

Dale Schunk and his colleagues have conducted an impressive body of research involving self-regulatory interventions (Schunk, 1990; 2001; Schunk & Zimmerman, 1997). One focus of several studies involved investigations of goal setting, self-efficacy, and feedback (e.g. Schunk & Ertmer, 1999; Schunk & Swartz, 1993). In a series of two

experiments, Schunk and Swartz (1993) examined the effects of progress feedback and different goals on self-efficacy and writing achievement. The fifth grade participants were assigned randomly to one of four experimental conditions: product (outcome) goal, process goal, process goal plus progress feedback, and general goal (control group). All students received strategy instruction. In both studies, the process goal plus progress feedback group had higher self-efficacy and greater writing skill acquisition than the general goal group. Self-efficacy was found to be highly predictive of strategy use and writing skill. Besides replication, the second study tested for generalization and maintenance of strategy use. Compared to the general goal group, process goal plus progress feedback students was correlated with greater self-efficacy for maintenance and for valuing of strategy. An emphasis on process goals is argued to focus attention on strategy use. Progress feedback provides information on how well a student is implementing strategies and lets them know how to adjust their skills.

In an experiment by Zimmerman and Kitsantas (1996) that involved high school girls learning dart throwing, similar results to the study above were found for the advantages of process goals over outcome goals. This latter study also extended the research by Schunk and Swartz by demonstrating that girls in each goal group who had been assigned additionally to self-record their learning progress experienced additive advantages over girls who did not self-record. Self-recording provided the learners with systematic feedback about their learning progress. It is important to note how these studies demonstrate the cyclical influences between processes from different self-regulatory phases.

Although attending to process-related aspects of performance during skill development is critical, it is also important to attend ultimately to performance outcomes. Research by Zimmerman and Kitsantas (1997, 1999) investigated the hypothesized enhancing effects of shifting from process goals to outcome goals once automaticity of desired skills was achieved. Using a motor skill (dart throwing) in the earlier study and an academic task (kernel sentence combining task) in the latter, they compared groups of learners who were assigned different types of goals. Using the dart throwing task, Zimmerman and Kitsantas (1997) assigned the participating high school girls to either a practice-only group or one of eight experimental conditions. The experimental groups were as follows: (1) outcome goal, (2) outcome goal and self-recording, (3) process goal, (4) process goal and self-recording, (5) transformed goal, (6) transformed goal and self-recording, (7) shifting goal, and (8) shifting goal and self-recording. The transformed goal condition referred to being trained to attend to particular process aspects of performance based on the outcomes that were self-monitored. In other words, the students were shown how to interpret outcome feedback to make adjustments in their strategies. The shifting goal group was taught to shift from process goals to an outcome goal once automaticity on the task was attained. As hypothesized, the latter goal group that shifted their process goals to outcome goals outperformed learners with no explicit goal and learners who were assigned a transformed goal, process goal, or outcome goal. These enhanced effects that were associated with shifting the emphasis of goals draw attention to the different forms of feedback that are involved in successful self-regulation. Process goals were more effective than outcome goals. Transformed goals had mostly similar effects as process goals, but had slightly more beneficial effects, including greater

self-efficacy beliefs. Systematic self-recording also enhanced the feedback for girls in each of the different goal groups, which resulted in greater performance, self-efficacy, and self-reactions.

In addition, Zimmerman and Kitsantas (1999) replicated both this study and the results using an academic writing task (although the transformed goal was not included in this investigation). This area of research has implications about how to structure feedback in a learning context so that the most effective progress is made towards challenging learning goals. Clearly, there is a dynamic interdependence between goals and feedback.

Self-Efficacy and Feedback

Self-regulated learners tend to exhibit high-perceived self-efficacy and a sense of personal agency. Self-efficacy beliefs refer to perceived capabilities to perform designated tasks to desired levels (Bandura, 1997). Self-efficacy is an essential source of motivation in learning and achievement (Pajares, 1996; Zimmerman, 2000). Self-efficacy beliefs help differentiate between resilient and non-resilient students (Borman & Overman, 2004). Perceived self-efficacy both directly influences goal setting, effort, and persistence, and indirectly influences other self-regulatory processes that affect performance and learning. Poor self-efficacy beliefs can lead students not to prepare adequately for tests (Zimmerman, 2002b). Research also shows that self-efficacy beliefs directly predict academic performance (Zimmerman, 2002a). Pajares and Miller (1994) used path analysis to demonstrate that self-efficacy beliefs were more predictive of math problem solving performance than prior experience with math, gender, math self-concept, and perceived usefulness of math. Furthermore, students' self-efficacy beliefs also mediated the effects of gender and prior math experience. Self-efficacy beliefs are better

predictors of academic performance than other self-constructs in part because they are more task- and context-specific. Self-concept and self-esteem are more globally assessed constructs and are less useful in predicting performance (Pajares & Miller, 1994; Zimmerman, 1995). Pajares and colleagues (Pajares, 1996; Urdan & Pajares, 2006) have called for more research directed at understanding sources of self-efficacy, including potential sources beyond the four highlighted by Bandura (1997)—mastery experience, vicarious experience, social persuasion, and emotional and physiological experience.

Goal Orientation and Feedback

Goal orientation has been identified as an important source of self-motivational beliefs and refers to the general pattern of beliefs regarding the purposes for engaging in achievement tasks along with general standards for self-evaluating learning or performance (Pintrich, 2000a; 2000b; Pintrich & Schunk, 2002). Learning goals refer to approaching a task for an intrinsic motivation, inherent value, and mastery approach. Performance goals are related to concern with outperforming others and displaying self-competence to others. Dweck and Elliott (1988) have viewed mastery-oriented students as concerned primarily with learning goals, while students exhibiting a pattern of learned helplessness tend to focus on performance goals. Thus, students with performance goals will be preoccupied with showing high-ability and hiding low-ability. Students with learning-focused goals are believed to more often seek challenging tasks and persist in their efforts than students with performance-focused goals (Ames & Archer, 1988). However, there is not necessarily a dichotomy between performance goals and learning goals. Learners can report having both types of goals, neither, or one or the other. It is widely argued in educational psychology that learners tend to have multiple,

simultaneous goals (Pintrich, 2000; Urdan & Maehr, 1995). Furthermore, the trend is to make distinctions along the goal dimension of approach and avoidance, particularly concerning performance goals. Although it is important to understand that the relationship between mastery and performance goals is not that individuals either have one or the other; evidence usually suggests that a mastery-orientation leads to the most positive, adaptive academic behavior patterns (Elliot & Dweck; 1988; Grant & Dweck, 2003; Meece & Holt, 1993).

Overall, for educators who are aiming to develop resilient learners who have the proclivity to overcome obstacles and challenges, it seems that the research points to the power of encouraging learning and mastery goals when compared to performance goals. For example, in research by Elliot and Dweck (1988), even students with perceived low ability demonstrated persistence at assigned tasks when learning goals were made salient. Although performance goals can predict positive outcomes when students experience success, the same is not true when these students experience setbacks and failures. Rather, in such contexts, students' motivation and performance are negatively impacted (Grant & Dweck, 2003).

Students' perceptions of goal structure or orientation in a learning context is a potential source for self-efficacy. In one recent study (Gutman, 2006) involving high school students who are African American, increases in mathematics self-efficacy was associated with perceived classroom mastery goal structure. Furthermore, perceived classroom mastery goal structure was also associated with higher mathematics achievement than perceived classroom performance goal structure. In addition, students with more mastery goals had significantly higher mathematics self-efficacy and

mathematics achievement. This research complements prior investigations at the elementary level and middle school levels (Ames, 1992; Midgley, 2002).

Contemporary emphasis on high-stakes, summative testing could lead to increasing student endorsement of performance-oriented goals and/or lower endorsement of mastery-oriented goals. However, Schunk (1996) has shown that self-evaluative processes can have even greater influence on learning than goal orientation, while the combination of learning goals and self-evaluation opportunities can have enhancing effects on self-efficacy and performance. In an example of classroom-based research that is pertinent to the immediate topic and the research proposal as a whole, Fuchs et al. (1997) conducted an intervention study designed to enhance elementary aged students' task-focused goal orientation and mathematics achievement for an entire academic year. Students with learning disabilities and students without learning disabilities were randomly assigned to one of three conditions. There was a task-focused treatment plus self-referenced assessment feedback condition, a self-referenced assessment feedback only condition, and a traditional instruction control condition. The task-focused treatment involved the use of peer assisted learning strategies, while the self-referenced assessment feedback was operationalized through weekly curriculum-based measures. Findings of the study showed that the task-focused plus curriculum-based measurement feedback treatment was associated with the highest mathematics achievement (assessed by an end-of-the-year tests), and the assessment feedback only condition outperformed the control condition.

Performance Control Phase

Self-Observation and Feedback

During the performance control phase, effective self-regulators self-monitor their implementation of plans, including their selected strategies. Self-observation processes in the performance phase of SRL include metacognitive self-monitoring and self-recording. Zimmerman (2008) distinguishes between the two processes by referring to metacognitive self-monitoring as being more general in attention focusing than self-recording, which involves more formal, systematic monitoring of deliberate aspects of learning or performance by tracking performance scores in written form or developing graphic depictions of progress on targeted behaviors (Kitsantas & Zimmerman, 2006). Self-recording one's progress is an example of how to create important feedback related to self-set goals. This self-monitoring feedback, among other sources of information, can provide guidance on strategic implementation of planned efforts. In the studies referred to earlier that involved both motoric learning (Zimmerman & Kitsantas, 1997) and writing revision (Zimmerman & Kitsantas, 1999), half of the students in each goal group were taught a self-recording strategy. In both sets of studies, the authors reported that self-recording enhanced learner performance, self-efficacy, and self-reactions.

Self-Reflection Phase

The capacity for self-reflection is a distinctively human quality (Bandura, 1986). Moreover, self-reflection is not only a capability, but a necessity (Dewey, 1916). During the self-reflection phase, learners evaluate their performance in comparison to their goals. They also determine the effectiveness of their strategies. Self-reflection is required to successfully adapt or transfer strategies in a non-habitual fashion. The adaptive use of

strategies is aided when individuals use feedback to monitor their effectiveness. An essential facet of self-reflection is individuals' reflection on their capabilities for action (Bandura, 1997).

The self-reflection phase of Zimmerman's (2000, 2002a) social cognitive SRL model involves self-judgments and self-reactions (see Figure 1). Subprocesses of these self-reflection processes are described next.

Self-Judgmental Processes

Self-evaluation. Self-evaluation is a form of self-judgment that refers to comparing self-observed performance to an absolute set standard or prior performance (Zimmerman, 2002a). Learners need to self-evaluate their performance and to determine the effectiveness of their strategy use for cyclical improvements in goal striving. Students who engage in frequent self-evaluation tend to have greater academic outcomes than those who do not self-evaluate (Fontana & Fernandes, 1994; Kitsantas, Reiser, Doster, 2004; Ross, Hogaboam-Gray, & Rolheiser, 2002; Schunk, 1996; Schunk & Ertmer, 1999).

In a recent study (Kitsantas & Zimmerman, 2006), the influence of graphing performance outcomes and self-evaluative standards in self-regulated learning was investigated. Specifically, graduated standards were compared with absolute high standards for differential effects on learning and performing a motoric task (dart throwing) as well as on motivational beliefs. It was expected that absolute high standards would be premature during the learning process. Absolute high standards would limit the focus of the students so that they did not attend enough to incremental steps of improvement. As hypothesized, graphing of performance during practice was associated

with greater performance and enhanced motivational beliefs, including self-satisfaction and self-efficacy. Self-evaluative and goal-setting processes have been investigated in various academic domains, also; including, mathematics (e.g. Schunk, 1996), reading and writing (see Schunk, 2003), and computer science (Schunk & Ertmer, 1999).

Causal attribution. Causal attributions are another mode of self-judgment, which refers to individuals' beliefs about why certain outcomes occur. Attributions about the causes of errors affect the impact of feedback on the learner. A characteristic of many unsuccessful learners is that they fail to attribute outcomes, particularly setbacks or failures, to internal, controllable causes, such as effort or use of learning strategies. They often will place blame on others, while not recognizing ways to control various environmental, personal, and behavioral learning processes (Zimmerman, 1995). Blaming others is one way that learners focus on attributing failures to external factors. Insufficient time and the difficulty of the task are other ways that attributions are made to external factors. Attributions to strategy use can be more empowering than attributions to ability, because they are perceived as controllable. This encourages persistence in attaining goals by going through successive SRL cycles. This self-reflective information is then adaptively applied to future forethought phases in a cyclical fashion. In fact, linking feedback regarding performance with strategy use is likely to be more beneficial than effort attributional feedback (see Schunk & Cox, 1986; Schunk & Gunn, 1986).

In addition to the distinction between internal and external sources of causation for successes and failures, Dweck (2000) and others have also characterized attributions in terms of stable versus unstable causes. By dwelling on a lack of ability, which is often viewed as a relatively stable factor, individuals will tend to self-react defensively to

outcomes instead of adaptively, and are likely to experience less self-satisfaction (Zimmerman, 2000, 2002a). An adaptive attribution approach would instead tend to emphasize the ineffective use of strategies for setbacks or insufficient progress towards desired goals. In addition, the stability dimension is a factor in learners' beliefs about ability or intelligence. Whether a learner views ability as a fixed, stable entity that is relatively unchangeable, or views ability as an incremental entity that is malleable, can have a powerful influence on self-regulated learning (Dweck &Leggett, 1988; Dweck, 2000). Researchers have shown that students' beliefs about themselves as learners can be changed from notions of fixed ability to beliefs that competence is developed (e.g. Blackwell, Trzesniewski, & Dweck, 2007).

Self-Reactive Processes and Feedback

Self-satisfaction reactions and adaptive or defensive inferences are highlighted as key self-reactive processes of the self-reflection phase of SRL (Zimmerman, 2000). The previous section explained that perceptions of control and progress can lead to a greater sense of self-satisfaction and adaptive inferences in the learning process. Self-satisfaction reactions are "perceptions of satisfaction or dissatisfaction (and associated affect) regarding one's performance" (Zimmerman, 2008, p. 183). Bandura (1997) wrote that "the self-satisfaction gained from progressive mastery and fulfillment of personal challenges serves as another enduring motivator of pursuits" (p. 132). Causal attributions and levels of satisfaction are closely related to the adaptive or defensive inferences that a learner makes, which refer to the conclusions about the need to adapt one's methods in further attempts at learning (Zimmerman, 2008). These inferences determine whether the

learner engages in self-enhancing cycles of self-regulation or instead withdraws from further efforts or engages in maladaptive cycles of self-regulation.

Two key areas of self-regulatory dysfunctions are 1) apathy or disinterest, and 2) reactive behaviors instead of proactive behaviors (Zimmerman, 2000). Students who are apathetic about their math performance will exhibit poor planning and performance control methods. Similarly, reactive students will tend to not use quiz feedback to proactively correct for learning and prepare for an upcoming test (Zimmerman, 2000). On the other hand, proactive self-regulated students monitor the effectiveness of their strategy usage and react to the feedback to adapt strategies or determine new ones (Zimmerman, Bonner, & Kovach, 1996). Learners will tend to not self-regulate if they do not value the skill or its outcomes (Boekaerts, Pintrich, & Zeidner, 2000; Zimmerman, 2002b). In addition, students are often poor judges of their learning outcomes (Dunning, Heath, & Suls, 2004). These points highlight the need to support learners with self-reflecting on learning in proactive ways.

To aid the development of these self-reflection processes in educational settings, students can be given explicit opportunities for self-reflection. For example, students can be supplied with added and improved occasions to revise prior work, such as quiz and test revision that requires them to critically examine patterns in their errors and successes. For both teachers and students, these learning opportunities can shift assessment activities to being viewed as formative, rather than just summative. Such efforts are aimed at fostering adaptive inferences rather than defensive inferences as students self-react to their performances. The next section of this chapter further elaborates on how SRL develops and, in some cases, how it is hindered.

Development of Academic Self-Regulation

Self-regulation is said to develop from both social sources and personal sources (Schunk & Zimmerman, 1997; Zimmerman, 2000). Numerous self-regulatory studies from a social cognitive perspective (e.g. Zimmerman & Kitsantas, 2002; see also Zimmerman & Kitsantas, 2005) have demonstrated the hypothesized sequentiality of the developmental phase model of self-regulation (see Table 2.2 for a summary of model adapted from Zimmerman, 2002b). Two key social sources of self-regulatory competence are modeling and externally derived feedback.

Table 2.2
Developmental Level Model of Self-Regulation (Zimmerman, 2002b)

Levels of regulation	Sources of regulation	Sources of motivation	Task conditions	Performance indices
Observation	Modeling	Vicarious reinforcement	Presence of models	Discrimination
Emulation	Performance and social feedback	Direct/social reinforcement	Correspond to models	Stylistic duplication
Self-control	Representation of process standards	Self-reinforcement	Structured	Automatization
Self-regulation	Performance/ outcomes	Self-efficacy beliefs	Dynamic	Adaptation

Modeling

The first developmental phase of self-regulation is an observational process, which involves the novice observing the performance of an expert. At the observation level, the learner carefully attends to an abstract model or a social model's performance

or learning. Observational learning through modeling involves the four subprocesses of attention, retention, production, and motivation (Bandura, 1986). The power of observational learning was evident as far back as the time of the ancient Greeks (Rosenthal & Zimmerman, 1978). It plays a central role in social cognitive theory due to its powerful effects on motivation and learning. According to Bandura (1986), our capability for vicarious learning vastly expands our potential for learning, which would otherwise be constrained by limited time, energy, or other resources. Repeated modeling in varying contexts can enhance acquisition. In addition, the presence of a coping model that demonstrates the self-monitoring of strategy implementation and correction of errors, rather than a mastery model that performs the task flawlessly, can also improve acquisition. Zimmerman (2002b) explained, “An observational level of skill has been acquired when a learner can discriminate qualitative levels in models’ performances” (p. 5).

The second phase of self-regulatory development involves the learner emulating the key features of the expert’s performance with the guidance of the expert. During the emulation phase, the learner practices the skill (enactive experience) and social feedback is provided. At the emulation level, the learner can discriminate the key components of the skill and perform the general form of the models’ skill. The third level shifts to the individual’s self-control of the strategy or skill on related tasks without the model being present. Lastly, the fourth level represents when the learner has achieved automaticity of the strategies and task performance, and is able to adapt approaches successfully to alternate (transfer) tasks and contexts. Self-regulation is greatly context-dependent, so high levels of self-regulatory competence in one domain or task are not necessarily

matched in other domains or tasks. This developmental model differs from the traditional approach of describing development in terms of discrete, fixed, linear stages. Instead, the model accounts for overlapping of phases and acknowledges that once a higher phase of skill development is attained the person may at a latter point return to a lower phase as deemed necessary. In addition, learners do not necessarily follow the same order of phases. Furthermore, although self-regulatory competence is predicted to originate from social sources and then shift to more internal sources, social influence can also be influential and necessary at the self-control and self-regulation phases (Schunk, 1999; Zimmerman, 2000).

Feedback

Feedback plays a critical role in academic self-regulation (Butler & Winne, 1995; Zimmerman 1989, 1995). The effectiveness of external feedback can be considered in respect to its *form* and *content* (Kulhavy & Stock, 1989). Feedback that focuses on outcome information connotes summative judgments about knowledge, skills, or abilities. In contrast, formative feedback can be defined as process-oriented information that leads to some sort of reformulation by the learner. In other words, it is suggestive of further steps to take in the learning process. Process-related feedback is a decisive source for self-regulation and self-efficacy beliefs because it helps the learner focus on task-specific components that are in need of improvement (Bandura, 1997; Schunk & Swartz, 1993). However, as was described earlier in this chapter when comparing the merits of shifting goals to process or outcome only goals, ultimately, performance outcomes are also essential to self-regulatory development of skill.

Many students are apathetic about their assessment results. In part, this can be due to dysfunctional attributions about the causes for a lack of prior success. Additionally, students tend to not self-regulate if they do not value the skill or its outcomes (Boekaerts, Pintrich, & Zeidner, 2000; Zimmerman, 2002b). It is important to consider how to provide feedback and how students interpret feedback in the educational context. For example, interactions between teacher and student regarding test performance feedback involve not just cognitive and behavioral responses but also motivational and affective responses. Assessment practices tend to emphasize normative grading rather than assisting progress in learning. Unfortunately, for many students, grading based on normative standards can have negative consequences due, in part, to an increased influence on interpersonal competition and social comparisons (Crooks, 1988). Such practices are likely to foster an educational environment with a performance-orientation or ego-involvement goal structure that is concerned primarily with summative evaluations of ability or achievement (Ames, 1992). Alternatively, an approach to instruction and assessment focused on mastery-oriented goals is deemed to be of greater benefit to the learner's success in school and beyond (Dweck, 2000). Intrinsic motivation is likely to be maintained or enhanced when feedback is individualized and task-related rather than normative-based (grading) or non-existent (e.g. Ruth & Nisan, 1986).

Feedback that is evaluative oriented has significant influence on competency and control beliefs, as well as choice of tasks (Nicholls, 1984). In turn, these self-regulatory processes hold substantial influence on performance attainments. For example, the power of frequent, self-referenced assessment feedback was demonstrated in an experiment by Schunk (1982). Children that received effort attributional feedback for prior mathematic

performance had improved subsequent self-efficacy beliefs, task involvement, and skill development on subsequent mathematic learning (Schunk, 1982). In further investigations, Schunk and colleagues found that ability feedback had stronger influence on self-efficacy and performance than effort feedback (Schunk, 1983; Schunk & Gunn, 1989). For example, Schunk (1983) studied the effects of both ability and effort attributional feedback on mathematical problem solving, self-efficacy, and achievement among third graders. The children participated in one of four conditions: ability only attributional feedback, effort only attributional feedback, ability and effort attributional feedback, and no attributional feedback. Results showed children who received only ability attributional feedback, such as, "You're good at this," judged self-efficacy the highest and successfully solved the most mathematics problems. These findings highlighted the complexities of self-perceptions and ability- and effort-related praise (Schunk, 1983).

Believing that competence is something that is developed has been shown to have powerful influence on self-regulatory functioning. For example, in a study involving an organizational decision making simulation by Wood and Bandura (1989), students who were induced to have incremental conceptions of ability had a resilient belief of self-efficacy, set challenging goals, and used strategies effectively. Unlike their counterparts, students who were induced to view ability as a stable entity, tended to report decreased self-efficacy, set lower goals, and were less effective in their use of strategies. Students focused on developing their competence are likely to be more receptive to using academic feedback for adaptive self-regulation. In another study (Bandura & Wood, 1989) involving the same decision making task as in the previous study, instructors who

set achievable goals, provided clear standards for self-evaluation, and provided corrective feedback helped students by enhancing their self-efficacy beliefs and helped students develop criteria for self-judgment. In turn, this facilitated students self-regulating their performance achievement. These same types of feedback were found to have similar positive effects in research reviewed by Kluger and DeNisi (1996). In their often-cited review of feedback-related research, the authors reported high effect sizes for feedback interventions that provided the correct answer (ES = .85) and feedback interventions that showed progress towards goals (ES = .98).

A common purpose of frequent assessment is to give students proximal feedback to self-monitor their progress. However, too often the reality in classrooms is that students are poor at self-monitoring their grades and learning progress. They might have a general sense of what their grade performances have been, but they do not systematically record their grades on a chart or by other means (Cleary & Zimmerman, 2004; Kitsantas & Zimmerman, 2006). Struggling learners tend to have poor calibration between their self-efficacy beliefs and actual performance by overestimating or underestimating their capabilities. In addition, post-performance self-judgments also are often inaccurate for these learners. In fact, learners tend not to be accurate observers of learning processes in general (e.g. Winne & Jamieson-Noel, 2002).

Inaccurate self-awareness is said to be pervasive among humans, including not only regarding academic learning, but also in the workplace and in our considerations of health (Dunning, Heath, & Suls, 2004). The tendency is for people to be overconfident (Metcalfe, 1998). There are various psychological mechanisms or processes studied by researchers to help explain the source of inaccuracy as well as how to intervene to

enhance accuracy. For example, the hypothesis that people engage in self-deception is one such explanation. This is a hypothesized mechanism in resilience research that is believed to benefit individuals with optimistic beliefs and judgments in situations such as cases of resilient cancer patients. However, the concept of literal self-deception problematically divides the self into multiple selves where one self attempts to "deceive" another (deep-rooted) self (Bandura, 1986). Optimistic patterns over longer-term events or life trajectories can be adaptive. However, more micro-level failures in self-assessment tend to be maladaptive and are often described as metacognitive biases.

Clear feedback about performance or progress can increase the accuracy of self-appraisals (Schunk, 1981; 1995). For example, Schunk (1995) has shown that instruction and self-evaluation practice opportunities can enhance accuracy between self-efficacy beliefs and performance. It is likely that struggling students require deliberate learning opportunities involving the effective use of academic feedback in an ongoing, cyclical fashion to improve both metacognitive self-awareness and performance.

The potential benefits of supporting students during cyclical reflection about their progress towards goals are evident in an experiment conducted by Schunk (1996) in which he investigated the effects of goal orientation and self-assessment opportunities on self-efficacy and math performance. Fourth graders were randomly assigned to one of four groups. One group was induced with a learning goal. Another group was assigned a learning goal plus self-assessment. A third group was assigned a performance goal. The last group was assigned a performance goal and self-assessment. All students participated in seven 45-minute sessions involving a series of tasks involving the computation of fractions. The self-assessment groups engaged in the self-assessment at the end of each of

the sessions. On post-intervention measures of self-efficacy and math performance, differences between learning and performance goals were not evident in the two groups that self-evaluated their performances. In a second study, all students were asked to engage in self-assessment of their performance just at the end of the training program. Results from the second study showed the learning goal group had higher self-efficacy and higher skills in adding fractions than the performance goal group. Note that the self-assessment activity masked or diminished the effects of goal orientation towards the math task.

Early investigations into self-regulated learning by Zimmerman and Martinez-Pons showed that self-regulation predicts test performance (1986, 1988, 1990). More recently, Kitsantas (2002) conducted a study with undergraduate psychology students to investigate the effects of self-regulatory processes on test preparation and test taking. Self-regulatory processes were measured using a structured interview questionnaire based on the instrument created by Zimmerman and Martinez-Pons (1986). Course exams were used to assess high and low achievers. As expected, high test scorers exhibited greater self-regulation in their self-reported strategy use before, during, and after the test. In other words, higher achievers were more self-regulated in their test preparation, test taking, and in the strategies implemented *after* receiving test performance feedback. Two self-regulatory strategies used after receiving test grades were found to be significantly different between high and low test scorers: goal setting and planning, and keeping records and monitoring. Although in the expected direction, non-significant differences were found for reviewing notes of old test, seeking information and help, and self-evaluation. Highly self-regulated students had greater self-efficacy beliefs and perceived

the test as more important. Furthermore, regression analysis showed that greater strategy usage predicted not only the test scores used as a dependent measure, but also a future test in the course. Of particular importance to the present discussion is that the highly self-regulated students in this study made constructive use of their test feedback for further learning enhancement and strong performances on future tests.

Final Comments

Historically, feedback has been conceptualized as a terminal outcome of learning efforts, and little attention was given to its proactive and self-motivating qualities. However, self-regulation models have described and explained these proactive qualities of feedback in terms of self-reflective processes, not only to understand and interpret personal feedback, but also to motivate and improve further efforts to learn. Unfortunately, there has been a paucity of research on self-reflective judgments and reactions to feedback, especially regarding adaptation and motivation of further efforts to learn. A social cognitive perspective is well suited to guiding such research because of its focus on self-enhancing, cyclical associations between self-reflection and forethought processes involved in adaptive self-regulation. The present empirical study investigates the effects of improved, more elaborative forms and processes of feedback on students' self-reflection processes and subsequent motivational beliefs during mathematical problem solving.

CHAPTER 3 METHODOLOGY AND PROCEDURES

Sample

Participants in this experiment were students recruited from a public university in the eastern United States. There were 52 students (31 women) in the final sample. Ages ranged from 17 to 41, and the average age was 22. The general ethnic composition was 19 African American, 17 Hispanic/Latino, 7 Asian American, 7 European American, and 2 students from multiple ethnic groups. English was the primary language of 36 participants, 5 Spanish, 3 Russian, 2 "Chinese", 2 Bengali, 1 Urdu, 1 Hebrew, 1 Akan, and 1 French. Using parents' occupations as a proxy to indicate high and low socio-economic status (SES), 26 were low SES, 11 were high SES, and 15 did not indicate their parents' occupations. Students reported a range of college majors, with the most frequent being: 12 Nursing, 9 Liberal Arts and Sciences, 5 Engineering, 5 Human Services, 4 Health Technology, 4 Design, and 3 Computer Science. Students reported their current or most recent math course. The breakdown by course level was 10 at the developmental mathematics level (elementary algebra), 20 at the 100-level (algebra, geometry, trigonometry), 15 at the 200-level (statistics, advanced algebra) and 7 at or above the 300-level (advanced statistics, precalculus, calculus). No correlation was found among course level and performance on the tasks in this study.

The experimenter asked for students' participation by visiting classrooms and by posting flyers around the college campus. Teachers encouraged students to participate, and one psychology teacher gave her students extra credit if they participated and wrote about their experience as a research participant. All students received a $20 incentive for their participation. The final sample excluded eight students because of deviations from the study protocol.

Task Materials

The mathematical task used in this study was challenging and engaging, yet presumably unfamiliar to the study pool (although widely familiar to UK audiences of a very popular game show). Many researchers have chosen to use recall tasks when studying the effects of feedback on learning. The present investigation sought to include a new type of learning task—one designed to require more complex, problem-solving processes such as planning, monitoring, and adaptation in acquiring performance skill. A unique problem-solving task was selected to prevent or minimize the chances of students having prior experience with the task, since the investigation was about acquisition processes. The difficult nature of the novel task ensured that most of the participants would not readily devise successful strategies to solve the problem.

Although different task variations were possible, for this study, students were presented with an *array* of six smaller numbers, each ranging from 1-10 and a three-digit *target* number ranging from 100-999 (e.g. array: 4, 2, 8, 3, 6, 9; target: 136). The objective of the task was to use basic arithmetic operations (i.e. addition, subtraction, multiplication, and division) to equal target number or arrive as close as possible to the target number. All administered tasks had multiple solutions equaling the target number exactly. Each number in the array could only be used once, but not all numbers had to be used in attaining the target number. Other criteria for the task included that only positive integers (i.e. 1 or greater) and whole numbers could be used (e.g. an individual cannot divide 13 by 6 and then use 2.2 in further calculations, and no exponents are allowed). Students received six minutes to solve each task.

Design and Procedures

Students were assigned randomly to one of five conditions, consisting of one control condition and four experimental conditions in an additive design (see Table 3.1). All participants were asked to solve multiple examples of the mathematical task described in the previous section.

The five conditions were as follows. Students in condition 1 (control) did *not* receive strategy instruction or any feedback about performance. In contrast, students in condition 2 were instructed how to use a task-specific strategy to solve the math problems, although they did not receive any feedback on problems solved during the learning phase. Students assigned to condition 3 were taught the same strategy for solving the task during the instruction phase, but also received summative feedback during the learning phase. *Summative feedback*, which indicated whether the solution was correct or incorrect, involved the experimenter calculating the student's answer and then comparing that answer to the target number. Students in condition 4 received formative feedback in addition to strategy training and summative feedback. *Formative feedback* involved the experimenter giving a concise verbal indication of the sources of the errors, such as, "Brackets were not used appropriately here," or "You did not divide accurately here". Lastly, condition 5 students, in addition to strategy training and receiving summative and formative feedback, were asked to correct their math task errors and describe what adaptations they made. The experimenter then indicated to the student the accuracy of their adaptations. This supplementary process of self-correction and subsequent feedback is labeled *adaptive feedback*. It was expected that the explicit opportunity to use the performance feedback in the adaptive feedback condition would be the most likely of all experimental conditions to lead to advantageous adaptations in solving further examples

of the math task being used in this study. It should be noted that students in conditions 4 and 5 who did not have an error on a math problem were told that they followed all the steps of the strategy correctly and were asked to try another problem.

Each one-hour session was conducted individually with participants in a quiet room at the college. First, students received an overview of the study and a written consent form (see Appendix A). Upon receiving consent, a brief self-report questionnaire was administered that consisted of several demographic questions pertaining to participants' age, gender, ethnicity, language use, primary caregivers' occupational status (SES measure), their chosen college major, and their current or most recent math course (see Appendix B).

Table 3.1
Experimental and Control Conditions

	Instruction phase			Learning phase – 3 tasks			Posttest phase
Group (*n*)	Instructions	Pretest – 1 task	Strategy training	Summative feedback	Formative feedback	Adaptive feedback	2 tasks & SRL scales
1 (*12*)	X	X					X
2 (*10*)	X	X	X				X
3 (*10*)	X	X	X	X			X
4 (*8*)	X	X	X	X	X		X
5 (*12*)	X	X	X	X	X	X	X

*Experimental conditions: (1) No strategy + no FB control group, (2) Strategy + no FB, (3) Strategy + summative FB, (4) Strategy + summative + formative FB, (5) Strategy + summative + formative + adaptive FB

All students participated in three phases: 1) an instruction phase, 2) a learning phase, and 3) a posttest phase. The purpose of the *instruction phase* was to introduce the objective and rules of the math task, have participants solve an initial example of the task as a pretest, and, in the four experimental conditions, model the use a specific multiphase strategy for solving the math task (a description of the strategy follows). The *learning phase* involved the students' completion of three math task problems, the experimental manipulation of performance feedback, and the manipulation of how feedback was used after each problem is solved. The final, *posttest phase* served to measure students' learning of the task with two final math task problems, each followed by an identical set of rating scales and open-ended response items for students to complete. For uniformity, the experimenter used a scripted protocol for each phase of the session. In summary, there were two manipulated factors in this experiment, strategy instruction and various forms of feedback, which were tested for differential effects on the dependent variables of the study.

Instruction phase

During the first phase, the experimenter verbally explained the directions for the mathematical task, including an explanation of the objective, rules, and criteria for successful problem solving (see Task Materials section and Appendix C). After the explanation of the math task, students were given an example problem to solve within six minutes, given a one-minute warning. For participants in all five groups, the experimenter indicated whether the students' answers were correct or incorrect (i.e. knowledge of results). Following this first attempt to solve a problem, participants in the four experimental groups were instructed on the use of a multi-step problem solving

strategy (see Appendix D) through the use of cognitive modeling techniques (Schunk & Zimmerman, 1997). The students in the no-strategy control group were not told about the strategy.

Learning phase

During this phase, all students were given three different math task problems and asked to solve each within six minutes (the experimenter uses a timer). After five minutes, students received a one minute warning to finish up by writing their best estimate for a solution. During this phase, students in groups 3, 4, and 5 will receive feedback from the experimenter after each math problem they solve. See above for a description of the three feedback groups.

Posttest phase

As a posttest, a final set of two math task problems were presented sequentially for students to solve. Before each task, students were asked to respond to a questionnaire item pertaining to their self-efficacy regarding that particular task. After each task, students completed a paper-and-pencil questionnaire to measure self-evaluation, error attributions, self-satisfaction standards, adaptation, anxiety, interest, and goal orientation (see example posttest task and scales in Appendix E). Microanalytic procedures were used in this study to measure self-regulatory processes (Bandura, 1977, 1986; Zimmerman, 2008). Each self-report scale was kept succinct in length, and the scales were administered immediately after solving a task (except for the self-efficacy measure that was assessed before solving posttest tasks). This was so that 'traces' of individual student's beliefs, judgments, and reactions could be assessed in close proximity to

performance behavior. Protocols for each experimental group are presented in Appendix F.

Measures

Mathematical Performance

Performance accuracy. For each mathematical task performance, the experimenter computed an accuracy score by first calculating out the student's solution formula and then taking the absolute value of the difference between the original target number and the answer from the student's formula. Difference scores greater than 100 were converted to the default value of 100. In addition, when no final solution was given or the student did not follow the criteria of the task (i.e. used a non-array number), the default value of 100 was used. The test-retest Pearson correlation was $r = .21$ (correlation of pretest task and posttest task).

Strategy adaptation. The presence or absence of an improvement in performance scores from task 5 to task 6 was used as a dichotomous measure of strategy adaptation (i.e. 1 = yes, score improvement, 0 = no improvement).

Self-Motivation

Self-efficacy. A measure of students' self-efficacy for solving each of the posttest math tasks was used. This measure was constructed following the guidelines of Bandura (2006). *Before* each posttest task, students were asked to examine the task and then indicate how confident they were that they can find a successful solution to the problem by marking their answer on a 10-point scale ranging from 1 = 'definitely not confident' to 10 = 'extremely confident' (see Appendix E for the posttest form that contains this scale

and the remaining scales described below). The test-retest Pearson correlation coefficient was $r = .64$.

Math task interest. Another one item scale was included after the posttest tasks to assess the students' interest in solving the math problems. Students were asked: *Compared to other math tasks you have done, how much did you enjoy solving this problem?* The 10-point response scale ranged from 'much less' to 'much more'. The test-retest coefficient was $r = .82$.

Goal orientation. A scale was developed to measure perceived goal orientation. Three different types of goal orientations were assessed with two items for each orientation type: mastery goal orientation, performance-approach goal orientation, and performance-avoid goal orientation. Items were adapted from the Patterns of Adaptive Learning Scales (Midgley, et al, 2000). An example of a mastery goal orientation scale item was: *It's important to me to improve my skills on this math task.* A performance-approach goal orientation scale item stated: *It's important to me to show others that I'm good at this math task.* Lastly, an example of a performance-avoid goal orientation was: *It's important to me that I keep others from thinking I'm not smart on this math task.* Students indicated their level of agreement with each statement on a scale from 1 to 10, ranging from 1 = "not at all true" to 10 = "completely true". The reliability coefficients for the three goal orientations were as follows: mastery was $r = .87$, performance approach was $r = .80$, and performance avoidance was $r = .79$.

Self-Judgment

Self-evaluation. After each problem-solving attempt during the posttest phase, students were asked, *How confident are you that your answer is correct?* Students

indicated their response on a scale ranging from 1 = 'definitely not confident' to 10 = 'extremely confident'. The test-retest bivariate correlation coefficient was $r = .20$, $p > .10$. Controlling for both posttest task performances, the partial correlation coefficient was $r = .37$.

Causal attribution. As a measure of students' attributions for making an error on during the posttest phase, an open-ended response question was included immediately after problem solving that asked: *If your answer to this problem is wrong, why do you think you didn't do better?* Based on prior research by Zimmerman and colleagues (Zimmerman & Kitsantas, 1999; Cleary & Zimmerman, 2001), these attributions were independently categorized by two coders into one of 10 categories: specific strategy, general strategy, confidence/ability, focus/concentration, effort, practice, distractions, time, and don't know/no response. An example of a specific strategy is, "I was only using one type of operation." An example of a general strategy is, "Didn't have a correct formula." Attributions pertaining to ability or confidence are exemplified by, "I am no good at math." The category of focus/concentration is exemplified by, "I made a mistake because I am rushing." An effort attribution example is, "I didn't try to solve it fast enough." The category of practice is exemplified by, "Was very hard for me but in class we have practice, maybe I needed more practice." A distraction attribution example is, "Maybe because I knew I was working under pressure." Attributions to time included, "Because I needed more time." The written attribution responses were entered into a spreadsheet that did not contain identification of participants' condition assignment to prevent bias in coding. In cases where a student indicated multiple reasons for errors, the first attribution was coded. Inter-rater agreement using Cohen's kappa (Cohen, 1967) was

.67, 95% CI (0.49, 0.84). The strength of agreement was considered good given some overlap of attribution categories. The final categories for each student's attribution were decided by mutual agreement.

Self-Reaction

Self-satisfaction scale. To measure how satisfied students' were with their math problem solutions during the posttest phase they were asked: *How satisfied are you with your problem solving effort?* The 10-point scale ranged from 'very dissatisfied' to 'extremely satisfied'. The test-retest reliability coefficient was computed to be $r = .63$.

Adaptive inferences. To assess intervention effects on students' adaptive inferences, after each posttest problem, students were asked: *If your answer to the problem is wrong, would you change your method or approach? (Yes or no).* The test-retest coefficient was $r = .50$.

Math anxiety. Students rated their level of math anxiety after each attempt to solve a posttest problem by answering the question: *How anxious do you feel about this math task?* Responses were indicated on a 10-point scale ranging from 'extremely anxious' to 'not at all anxious'. The reliability coefficient was $r = .63$.

Calibration of Self-Appraisals

Self-efficacy bias. The calibration bias or direction of error between students' self-efficacy beliefs and their actual performance was assessed by subtracting '10' from their self-efficacy rating if the problem was solved correctly, or by subtracting '1' if there was an error (Pajares & Graham, 1999; Schraw, Potenza, & Nebelsick-Gullet, 1993). The scale ranged from -9 to +9. Therefore, a student who was 'extremely confident' (10), but was actually incorrect (1), received a bias score of -9 (1 minus 10). In contrast, if that

same student had indicated they were ‘definitely not confident (1), the bias value would have been 0 (1 minus 1).

Self-evaluation bias. The bias of participants’ self-evaluative judgments was also used as a measure of calibration. The degree of bias was computed in the same manner as with self-efficacy bias.

Hypotheses

It was hypothesized that there would be a positive linear trend in posttest performance as the group number increases from group 1 (control) to group 5 (strategy training + summative feedback + formative feedback + adaptive feedback). In addition, pairwise differences were expected between adjacent condition groups—with group 5 outperforming group 4, group 4 outperforming group 3, group 3 outperforming group 2, and group 2 outperforming group 1. Similar differences were predicted for students’ self-reflection phase processes, including self-evaluation, causal attributions, self-satisfaction, and adaptive inferences, as well as forethought phase self-motivation beliefs, such as self-efficacy, intrinsic interest, and goal orientation. Based on a social cognitive model of self-regulated learning, it was also expected that there would be positive correlations between self-regulatory processes and task performances.

CHAPTER 4 RESULTS

This chapter consists of five major sections. The first section involves preliminary analyses. Following next, is a section on the differences between the control and experimental groups in math task performance as a function of strategy instruction and levels of feedback. The third section involves examinations of the effects of strategy instruction and feedback on SRL beliefs and processes, and is presented in three sub-sections: self-judgments, self-reactions, and self-motivational beliefs. In the fourth section, analyses of calibration measures are discussed. The final section presents correlation analyses.

Preliminary Analyses

The original intention was to aggregate the two posttest performances to get a single performance measure, and do the same for each of the self-regulated learning measures. However, the first posttest task was not included in the analyses because fewer than 25% of the participants scored above zero, and performance on this task was negatively correlated with scores on the other tasks. Note that in the prior chapter, test-retest correlations were provided for self-regulated learning processes by correlating scores from both sets of posttest scales. However, like the first posttest performance scores, the first set of SRL scores were left out of the analyses in this chapter.

A preliminary analysis was conducted to examine whether gender was correlated with performance on the final posttest math task. No relationship between gender differences and performance were found, so data was pooled for further analyses. Differences in pretest scores between experimental and control groups were tested using ANOVA with a .05 significance criterion. Results indicated there were no significant

differences among the experimental groups in pretest scores, $F(4, 47) = .58$, $p = .68$. Furthermore, performance on the pretest was not correlated with the dependent measures, and as a result, the pretest was not used in subsequent analyses.

Math Performance

Dependent variable means and standard deviations for the control and experimental conditions are shown in Table 4.1. Two performance measures are presented in this section: performance accuracy and strategy adaptation.

Performance Accuracy

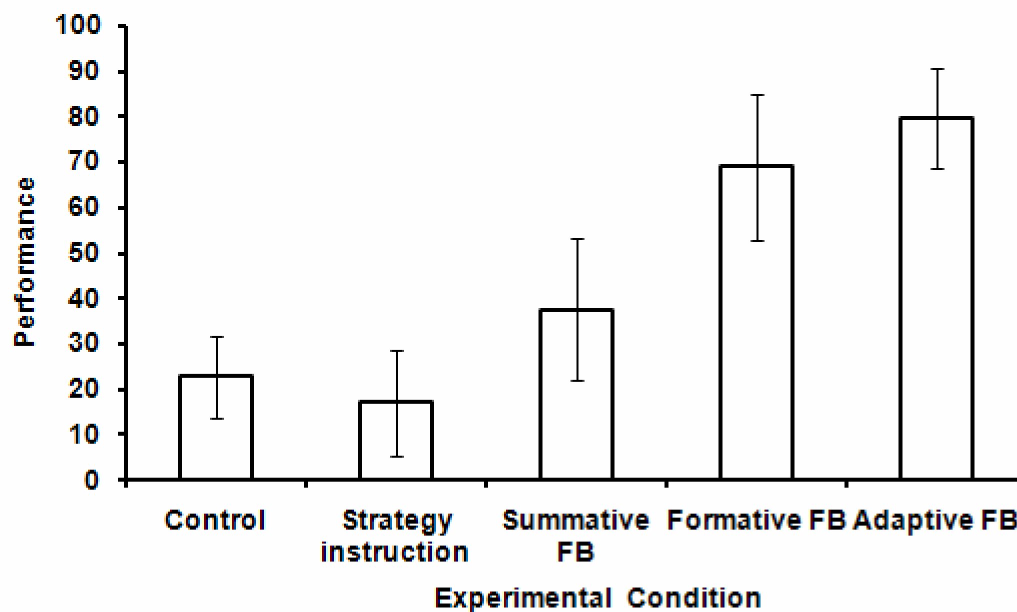
The students' mean posttest performance accuracy is shown graphically as a function of their treatment level in Figure 4.1. The treatment level was based on the amount of elaborative feedback that was provided. The treatment groups were ordered as follows: 1) control, 2) strategy instruction, 3) strategy instruction plus summative feedback, 4) strategy instruction, summative feedback, and formative feedback, and 5) strategy instruction, summative feedback, formative feedback, and adaptive feedback. A trend analysis was conducted between the experimental group level and performance accuracy. The assumption of homogeneity of variance between groups was supported by the non-significant Levene's test statistic. As hypothesized, a significant positive linear trend was found, $F(1, 50) = 22.24$, $p < .001$, $\eta^2 = .31$, suggesting that the additive increase in elaborative feedback led to higher posttest task performance. Quadratic and cubic contrasts were non-significant.

Table 4.1
Posttest Means (and Standard Deviations) for Dependent Measures

	Experimental condition				
	1	2	3	4	5
Dependent measures	*n* = 12	*n* = 10	*n* = 10	*n* = 8	*n* = 12
Performance	22.83 (31.02)	17.00 (36.28)	37.60 (49.03)	69.00 (45.55)	79.67 (31.02)
Self-evaluation	2.83 (1.80)	3.10 (3.11)	5.70 (3.40)	7.63 (3.16)	6.50 (4.10)
Self-satisfaction	3.25 (2.14)	5.40 (2.88)	6.30 (3.16)	7.75 (2.25)	7.00 (2.37)
Anxiety	5.42 (2.19)	5.00 (2.49)	4.80 (3.43)	5.50 (3.85)	5.50 (2.39)
Interest	6.17 (2.33)	6.60 (2.84)	7.10 (2.60)	5.75 (3.69)	7.67 (2.19)
Self-efficacy	4.00 (2.34)	4.80 (2.90)	5.70 (2.63)	5.71 (2.56)	5.83 (2.12)
Mastery approach	7.17 (2.64)	7.90 (1.79)	8.50 (1.90)	7.69 (2.56)	8.54 (2.36)
Performance approach	4.54 (2.62)	3.45 (2.58)	3.50 (2.94)	3.44 (2.34)	5.42 (3.21)
Performance avoidance	4.21 (2.72)	2.70 (2.36)	3.05 (2.89)	3.88 (2.53)	3.75 (2.78)

*Experimental conditions: (1) No strategy + no FB control group, (2) Strategy + no FB, (3) Strategy + summative FB, (4) Strategy + summative + formative FB, (5) Strategy + summative + formative + adaptive FB

Figure 4.1
Posttest Performance Accuracy for Experimental and Control Groups



A priori contrasts between specific pairwise experimental and control group differences in performance accuracy were conducted using *t* tests. These analyses of contrasts showed that the adaptive feedback group's performance (M = 79.67, SE = 11.12) was significantly greater than that of the control group (M = 22.83, SE 8.96, p < .01), the strategy instruction only group (M = 17.00, SE = 11.47, p < .01), and the summative feedback group (M = 37.60, SE = 15.51, p < .05), but not the formative feedback group (M = 69.00, SE = 16.10). The formative feedback group was also significantly different from the no strategy instruction group (p < .05) and the strategy instruction only group (p < .01), but not the summative feedback group. The summative feedback group did not differ significantly from the control group or strategy only group, and the strategy only group was not significantly different from the control group.

Thus, greater levels of feedback during practice led to an overall significant linear increase in math task performance. However, comparisons among the ordered feedback

groups revealed statistically significant increases in performance between the formative feedback and no feedback groups (4 > 1 and 2), as well as between the adaptive feedback group and the summative feedback group (5 > 3) and no feedback groups (5 > 1 and 2).

Two further tests for differences in posttest accuracy scores were conducted to compare feedback versus no feedback, and strategy training versus no strategy training. An ANOVA revealed a significant effect for feedback on posttest performance, $F(1, 50) = 13.54$, $p < .01$, $\eta^2 = .21$. However, the effect of strategy training was not statistically significant, $F(1, 50) = 3.73$, $p = .06$, $\eta^2 = .07$.

Math Strategy Adaptation

To investigate potential differences in self-adjustments from one task to the next between experimental groups, the presence or non-presence of an improvement in performance accuracy from task 5 to task 6 was used as a measure of strategy adaptation (dummy coded). The observed percentage of students who adapted their performance on the posttest was 25% for group 1, 20% for group 2, 40% for group 3, 75% for group 4, and 83% for group 5. A chi square analysis revealed a significant difference overall between experimental groups in adaptation during the posttest phase, $\chi^2 = 14.28$, $df = 4$, $p < .01$ (see Table 4.2). In addition to being a test of statistical significance, Cramer's V is also a measure of the strength of a relationship, i.e. a measure of effect size. The value of this test statistic was $V = .52$, which is considered a medium to large effect size (Cohen, 1988).

Table 4.2
Chi-Square Analysis of Adaptation Between Experimental and Control Groups

		Adaptation				Effect size
Condition	*n*	Yes	No	χ^2	*p*	*Cramer's V*
1	12	3	9	14.28	< .01	.52
2	10	2	8			
3	10	4	6			
4	8	6	2			
5	12	10	2			
Totals	52	25	27			

Partitioning of the chi-square test of independence was used to compare different collapsed groups. As expected, students that had adaptive feedback opportunities during practice (group 5) showed greater adaptation in their strategy use during the posttest than all of the other groups combined, $\chi^2 = 7.77$, $p < .01$ (see Table 4.3). In addition, a chi square test between the combined formative/adaptive feedback conditions (groups 4 and 5) and the combined summative feedback/no feedback groups (groups 3, 2, and 1) revealed an even stronger difference in the proportion who made adaptations, $\chi^2 = 13.27$, $p < .001$, and the effect size as measured by the phi-coefficient was .51. Thus, significantly greater levels of strategy adjustment were associated with feedback that elaborated on the source of errors during learning attempts.

Another examination was made of differences in strategy adaptation between groups receiving feedback (groups 3, 4, and 5) and the no feedback groups (groups 1 and

2). The test for independent means was significant, $\chi^2 = 9.82$, $p < .01$, $\varphi = .43$. The participants who received feedback during the learning phase were more likely to adapt their technique in the posttest phase (67%) than did students who did not receive feedback (23%). One last test regarding strategy adaptation was used to compare strategy instruction (55%) to no strategy instruction (25%). However, this test narrowly missed statistical significance, $\chi^2 = 3.33$, $p = .07$, $\varphi = .25$. Note that in this last comparison the control group adaptation cell had fewer counts (three) than the recommended minimum of five per cell.

Table 4.3
Partitioning the Chi Square: Strategy Adaptation

Contrast		χ^2	p	φ
Adaptive feedback	5 > 4 + 3 + 2 + 1	7.77	.005	.39
Formative or adaptive feedback	5 + 4 > 3 + 2 + 1	13.27	.000	.51
Feedback > no feedback	5 +4 +3 > 2 + 1	9.82	.002	.43
Strategy = no strategy	5 + 4 + 3 + 2 = 1	3.33	.068	.25

Self-Judgments

Self-Evaluation

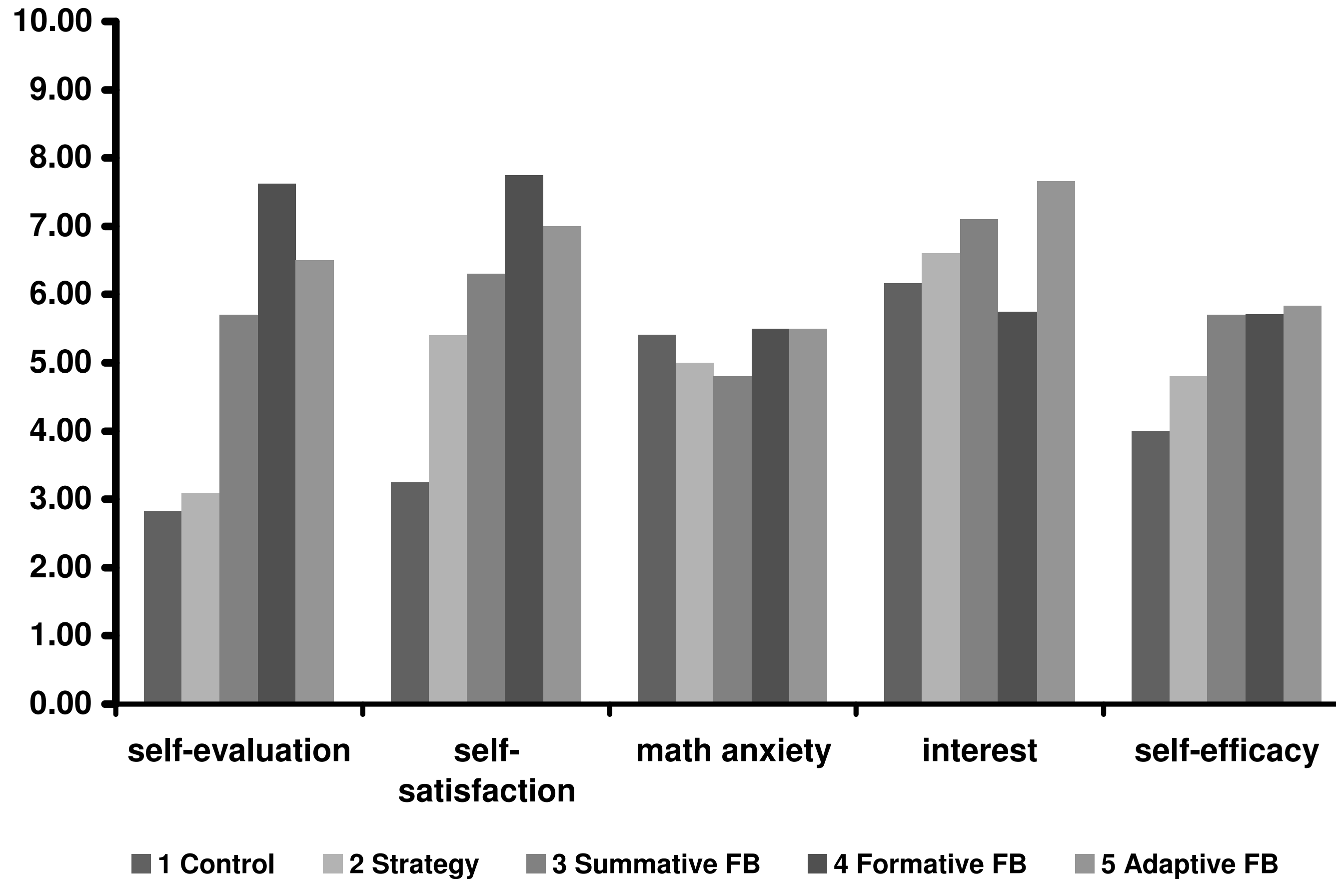
How learners self-evaluate performance in relation to standards or goals is an important self-reflection process. Immediately after their posttest performance, students were asked to rate in written form how confident they were that their response was

correct. Figure 4.2 graphically depicts means for self-evaluation and other SRL process measures. An ANOVA was used to compare self-evaluative judgments between conditions. The omnibus F-test was significant, $F(4, 47) = 4.38$, $p < .01$, $\eta^2 = .27$ (see Table 4.4), indicating that there was an overall positive linear trend from group 1 (control) to group 5 (adaptive feedback).

Furthermore, a priori contrasts revealed that the adaptive feedback condition (group 5, $M = 6.50$, $SE = .92$) had significantly higher self-evaluative judgments than the strategy only condition ($M = 3.10$, $SE = 1.01$, $p < .05$), as well as the control condition ($M = 2.83$, $SE = .92$, $p < .01$). The formative feedback group ($M = 7.63$, $SE = 1.13$) also had significantly greater self-evaluative judgments than the strategy only group and the control group (both ps $< .01$). Group 3, the summative feedback condition, had significantly higher self-evaluative judgments than the control group ($p < .05$), but not the strategy only group ($p = .08$). Note that the formative feedback group had the highest observed mean for self-evaluation; however, the mean was not significantly greater than the mean for the adaptive feedback group.

As was done with performance scores, two further tests for differences in self-evaluation were conducted to compare separately effects of feedback and strategy instruction to control groups. First, the comparison of feedback ($M = 6.53$, $SD = 3.60$) to no feedback ($M = 2.96$, $SD = 2.42$) revealed a statistically significant result, $F(1, 50) = 16.31$, $p < .001$, $\eta^2 = .25$. Likewise, a statistically significant effect of strategy training on self-evaluation was found (strategy training: $M = 5.68$, $SD = 3.76$, $n = 40$, $F(1, 50) = 6.36$, $p < .05$, $\eta^2 = .11$).

Figure 4.2
Bar Graph of Mean SRL Processes by Experimental and Control Conditions



* Note that higher values on the math anxiety scale indicated lower levels of anxiety.

Table 4.4
Analysis of Variance for Intervention Effects on Self-Regulatory Measures

Variable	Source	*SS*	*df*	*MS*	*F*	*p*	η^2
Self-evaluation	Between	179.44	4	44.86	4.38	.004	.27
	Within	481.54	47	10.25			
Self-satisfaction	Between	129.83	4	32.46	4.89	.002	.29
	Within	312.25	47	6.64			
Anxiety	Between	4.23	4	1.06	.13	ns	
	Within	381.52	47	8.12			
Interest	Between	23.54	4	5.89	.81	ns	
	Within	341.13	47	7.26			
Self-efficacy	Between	27.95	4	6.99	1.12	ns	
	Within	286.80	46	6.24			
Mastery approach	Between	15.16	4	3.79	.73	ns	
	Within	245.27	47	5.22			
Performance approach	Between	34.27	4	8.57	1.10	ns	
	Within	364.59	47	7.76			
Performance avoidance	Between	16.24	4	4.06	.57	ns	
	Within	336.68	47	7.16			

Causal Attributions

Participants' attributions following failures to reach the target answer during the posttest were classified into one of 10 categories: specific strategy, general strategy, confidence/ability, focus/concentration, effort, practice, distractions, time, don't know/no response, and other. Table 4.5 presents the percentage of attributions for each experimental and control group. Percentages are reported rather than frequencies because not all participants had an error on the posttest. These categories were collapsed into three superordinate attribution categories to facilitate statistical analysis: specific strategy,

general strategy, and distraction. The general strategy category subsumed the effort and practice classifications. The distraction category subsumed confidence/ability, focus/concentration, and time. The categories of don't know/no response and other were not included in the analysis because they did not fit into the two superordinate categories.

Table 4.5
Percentage of Attributions for Experimental and Control Groups after Missing Target Answer

	Experimental condition				
Attribution types	1 (*n* = 12)	2 (*n* = 10)	3 (*n* = 7)	4 (*n* = 4)	5 (*n* = 5)
Specific strategy	0.17	0.30	0.00	0.00	0.20
General strategy	0.33	0.20	0.14	0.00	0.20
Confidence/ability	0.00	0.30	0.29	0.50	0.00
Focus/concentration	0.00	0.00	0.00	0.00	0.20
Effort	0.00	0.00	0.00	0.00	0.20
Practice	0.17	0.00	0.00	0.00	0.00
Distractions	0.08	0.00	0.14	0.25	0.00
Time	0.25	0.00	0.14	0.25	0.00
Don't know/ no response	0.00	0.10	0.29	0.00	0.20
Other	0.00	0.00	0.00	0.00	0.00

Experimental conditions: (1) No strategy + no FB control group, (2) Strategy + no FB, (3) Strategy + summative FB, (4) Strategy + summative + formative FB, (5) Strategy + summative + formative + adaptive FB. Number of cases is limited to those with less than 100% accuracy.

Chi-square analysis revealed a marginally significant difference in attributions among the experimental and control conditions, $X^2 = 8.61$, $df = 4$, $p = .07$. Due to the

small sample size (n = 33), the more conservative likelihood ratio test was also computed, $\Lambda = 10.35$, $p = .04$. Using the phi-coefficient as an estimate of the effect size, a moderate effect size was obtained, $\Psi = .51$. Interestingly, the adaptive feedback group and the two no feedback groups were more likely to attribute errors to strategy, while the summative and formative feedback groups were more likely to attribute errors to distraction, $X^2 = 8.09$, $df = 1$, $p = .004$, $\Lambda = 8.89$, $df = 1$, p = .003. The phi coefficient was again of moderate effect size, $\Psi = .50$. Chi-square analysis revealed a significant difference in error attribution between the adaptive feedback group and the combined summative and formative feedback groups, $X^2 = 5.31$, $df = 1$, $p = .02$; $\Lambda = 5.27$, $p = .02$. The measure of effect size was moderate to large, $\Psi = .64$.

Self-Reactions

Self-Satisfaction

As with examining differences in self-evaluation, a single factor ANOVA was used to test overall differences between conditions regarding participants' self-satisfaction with their performance effort. The omnibus F-test was statistically significant, $F(4, 47) = 4.89$, $p < .01$, $\eta^2 = .29$. A priori contrasts revealed that the level of self-satisfaction following the posttest task was statistically greater for the adaptive feedback group than that of the control group (both $p < .01$), but not statistically greater than the other conditions. In the same manner, the other two feedback conditions were also statistically greater than the control group ($p < .01$), but not the other groups. A comparison of self-satisfaction levels between the feedback groups combined ($M = 6.97$, $SD = 2.61$) and the no feedback groups ($M = 4.23$, $SD = 2.67$) revealed a statistically significant difference, $F(1, 50) = 13.73$, $p < .001$, $\eta^2 = .22$. Similarly, the difference

between the strategy training groups combined ($M = 6.58$, $SD = 2.73$) and the control group was statistically significant ($F(1, 50) = 15.01$, $p < .001$, $\eta^2 = .23$).

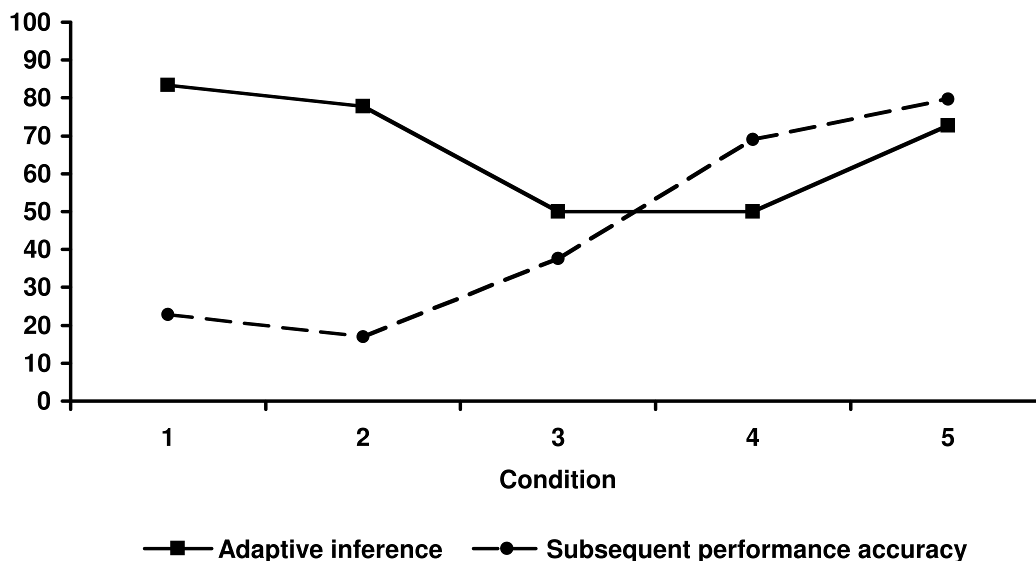
Adaptive Inferences

Recall that students were asked whether they would adjust their technique if their response to the math task was wrong. Unexpectedly, posttest performance was correlated negatively with students making an adaptive inference (i.e. indicating that they would make an adjustment in their approach to solving the next task), $r = .35$, $p < .05$. A chi-square analysis revealed a significant difference in adaptive inferences between conditions overall, $X^2 = 13.52$, $df = 4$, $p < .05$. Using the phi-coefficient as a measure of effect size, $\Psi = .52$, a moderate effect size was obtained. However, when only students who needed to adapt their methods (i.e. did not have a perfect score of 100) were tested for group differences, the Pearson chi-square test was not statistically significant. Thus, similar percentages of participants in each group inferred that they would need to adapt their approach in a subsequent task trial.

In Figure 4.3, the percentages of students in each condition that said they would adapt their methods after attempting to solve the first posttest task is plotted along with the subsequent performance scores on the final task. Self-report data in reference to the first posttest task was included here because it offered an opportune test of learners' responses to failure (on the excessively difficult task). A visual inspection of the chart reveals that the adaptive feedback group had the greatest pairing of adaptive inferences matched with actual strong performance on the following task. The formative feedback group and the summative feedback group were more congruent on these two variables than the groups that did not receive feedback. The two no-feedback groups reported they

would make changes in their methods to problem solving, but their subsequent performance suggests either they did not adjust their approach or their adaptations were insufficient to the demands of the task.

Figure 4.3
Adaptive Inference and Subsequent Performance Accuracy



Anxiety

Participants' anxiety regarding the math task was measured by a single self-report item (*M* = 5.25, *SD* = 2.75). The single item anxiety scale was not correlated significantly with any other dependent measure. The omnibus F-test revealed that there was no significant difference in anxiety means between the control and experimental groups.

Self-Motivation Beliefs

Self-Efficacy

The overall F-test to investigate differences between groups in students' self-efficacy was not statistically significant, $F(4, 46) = 1.12$, $p = .36$. However, further analyses of differences in self-efficacy that compared the combined feedback groups (*M*

= 5.76, *SD* = 2.33) to the no feedback groups (*M* = 4.36, *SD* = 2.57) revealed a statistically significant F-test, *F(*1, 50) = 4.11, *p* < .05, although a small effect size η^2 = .08. The difference in self-efficacy between the combined strategy instruction groups (*M* = 5.51, *SD* = 2.48) and the control group was not statistically significant (*F*(1, 50) = 3.50, *p* = .07, η^2 = .07).

Task Interest

The level of math task interest was relatively equal across experimental conditions. The adaptive feedback group's mean was 7.67 (*SD* = 2.19) on a 1-10 scale, and the lowest mean was actually the formative feedback group, 5.75 (*SD* = 3.69). The omnibus F-test showed the five experimental groups to be statistically the same, *F(*1, 50) = .81. Task interest was significantly related to self-evaluation (*r* = .35, *p* < .05) and self-satisfaction (*r* = .36, *p* < .01), but *not* significantly correlated with performance (*r* = .26, *p* > .05) or strategy adaptation (*r* = .21, *p* > .05).

Goal Orientation

A series of one-way ANOVAs revealed no significant differences among experimental groups regarding the three goal orientations included in this study: mastery approach, performance approach, and performance avoidance. Note that the performance approach goal orientation scale was correlated significantly only with self-evaluation (*r* = .27, *p* < .05) and interest (*r* = .28, *p* < .05). Mastery approach and performance avoidance goal orientations were not correlated with each other or other dependent measures, besides performance approach goal orientation (*r* = .31, *p* < .05; *r* = .80, *p* < .001, respectively).

Calibration

The degree of calibration between self-beliefs and actual behavior is an important dimension of metacognitive monitoring. Over-optimistic or over-pessimistic judgments can have negative motivational effects on choice, effort, and persistence. Calibration bias was examined for both the self-efficacy and the self-evaluation scales. See Table 4.6 for descriptive statistics for the calibration bias measures, as well as Figure 4.4 for a chart of the means for both measures.

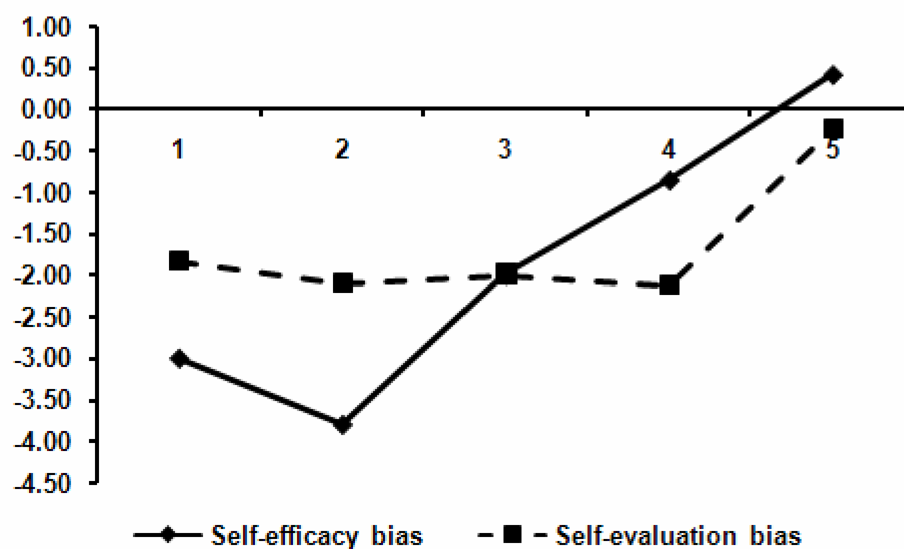
Table 4.6
Means and Standard Deviations of Calibration Bias of Self-Efficacy and Self-Evaluation Judgments

	Self-efficacy bias			Self-evaluation bias		
Condition	*N*	*M*	*SD*	*N*	*M*	*SD*
1	12	-3.00	2.34	12	-1.83	1.80
2	10	-3.80	2.90	10	-2.10	3.11
3	10	-2.00	4.00	10	-2.00	2.94
4	7	-0.86	4.91	8	-2.13	3.36
5	12	0.42	4.91	12	-0.25	3.60

Self-Efficacy Bias

Regarding differences in mean self-efficacy bias between experimental conditions, I found that the overall F-test was not statistically significant, $F(4, 46) = 2.05$, $p > .10$. A priori t-tests revealed that the adaptive feedback condition ($M = .42$, $SD = 4.91$) had significantly less biased self-efficacy beliefs than both the control group (M = -3.00, SD = 2.34, $p < .05$) and the strategy training only group ($M = -3.80$, $SD = 2.90$, $p < .05$).

Figure 4.4
Mean Calibration Bias of Self-Efficacy and Self-Evaluation Judgments by Condition



Further comparisons revealed that the combined feedback groups had an overall self-efficacy bias (*M* = -.72, *SD* = 4.57) that was less than that of the no feedback groups (*M* = -3.36, *SD* = -.72, *p* < .05). However, the F-test between strategy instruction groups (groups 2 through 5, *M* = -1.51, *SD* = 4.39), and the control group was not statistically significant, *F(*1, 49) = 1.26, *p* > .10.

Self-Evaluation Bias

An ANOVA was also used to test experimental group differences in self-evaluation bias. As was found with self-efficacy bias, the omnibus F-test for self-evaluation bias was not significant. There were no significant differences among the ordered pairs in the a priori contrasts. Both a comparison between feedback and no feedback and a comparison of strategy instruction and no strategy instruction revealed no significant differences in self-evaluation bias between collapsed groups.

Correlations Among Dependent Variables

Zero-order correlations among dependent variables are presented in Table 4.7. These results support key hypotheses of a cyclical phase model of self-regulation. Significant correlations were found among self-reflection phase self-judgments and self-reactions. For example, students' self-evaluation judgments correlated significantly with their self-satisfaction reactions (r = 0.71***) and their actual strategy adaptation (r = 0.50***). There is also evidence that these self-reflection phase self-judgments and self-reactions correlated cyclically with forethought phase self-motivational beliefs. For example, self-satisfaction reactions correlated significantly with self-efficacy (r = 0.54***) and task interest (r = 0.54***). Self-efficacy was correlated significantly with all other self-motivation measures. Interestingly, mastery goals and mastery avoidance goals did not correlate with other self-motivation variables, with one exception: Performance approach goals did correlate significantly with self-evaluation (r = 0.27*). However, the three goal orientation measures did intercorrelate significantly.

Table 4.7
Correlations Among Dependent Variables

	1	2	3	4	5	6	7	8	9
1. Performance	-								
2. Strategy adaptation	0.91***	-							
3. Self-evaluation	0.60***	0.50***	-						
4. Self-satisfaction	0.42**	0.33*	0.71***	-					
5. Anxiety	0.01	-0.05	0.18	0.16	-				
6. Interest	0.26	0.21	0.35*	0.36**	-0.01	-			
7. Self-efficacy	0.35*	0.30*	0.46**	0.54***	0.15	0.42**	-		
8. Mastery approach	0.12	0.07	0.18	0.06	0.02	0.25	0.31*	-	
9. Performance approach	0.26	0.17	0.27*	0.24	-0.13	0.28*	0.16	0.37**	-
10. Performance avoidance	0.04	-0.01	0.22	0.15	-0.05	0.10	0.18	0.25	0.80***

*** Correlation is significant at the 0.001 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

CHAPTER 5 DISCUSSION

Based on a social cognitive model of self-regulated learning (Zimmerman, 2000), this study aimed to investigate how increasing levels of elaborative feedback after cognitive modeling affects student post-practice performance and self-regulatory processes and motivational beliefs. At the onset of learning a novel, complex task, modeling alone may be insufficient to the acquisition of self-regulatory competence. The corrective role of feedback in the development of self-regulatory skill can enhance the influence of modeled instruction, such as the multi-step strategy that was demonstrated to the experimental group participants in this study.

As stated in the introduction to this investigation, it is particularly important to understand the processes of adaptation among learners' responses to academic feedback. After all, the ultimate goal of emphasizing an assessment-for-learning approach in the classroom is that academic feedback leads to enhancing self-regulatory cycles among the students. The common educational view of feedback is that it is information given to students about their levels of academic attainment, with the implicit assumption that students compare it with desired levels of attainment (i.e., self-evaluation). However, based on its cybernetic origins, a more precise use of the term feedback links it inextricably to an individual regulating something (Black & Wiliam, 1998), such as cognition, motivation, or behavior. From the agentic perspective (Bandura, 1997; 2008), a critical determinant of the self-regulated use of performance information lies with the self-reflective judgments and reactions of the individual. Proactive self-regulated learners tend to make strategic adjustments based on how they judge and react to their performance phase feedback and outcomes (Zimmerman, 2000). For this reason, the role of self-reflection is particularly important when teachers expect students to cognitively

process the results of assessment activities, self-motivate, and improve further learning efforts.

Math Performance

This study provided supportive evidence for several aspects of a social cognitive view of self-regulation and feedback. First, further support was found for the enhanced effects of progressively elaborative feedback in learning. In the context of a brief learning session, formative feedback that provided participants with information about the source of errors was associated with higher levels of performance than not providing feedback.

More significantly, the positive effects of formative feedback on cycles of self-regulation improved with the addition of adaptive feedback conditions involving guided practice in making strategy adjustments based on the formative feedback. The process of helping learners explicitly apply feedback towards learning adjustments is what is at the core of optimal self-regulatory development. These findings corroborate with results from other self-regulated learning research (e.g. Schunk, 1998) that demonstrate the enhancing effects of self-reflective practice (Schunk & Zimmerman, 1998).

Somewhat expectedly, summative feedback, which indicated the outcome of performance, did not yield a significant advantage to the participants in this study when directly compared to the no feedback conditions. However, clear support was found for the overall positive linear effects of increasing feedback elaboration levels. Trend analyses are valuable because they provide a broader assessment of the data. Plus, the presence of statistical error in a measure that departs from linearity can be tested directly.

Strategy Adaptation

Besides the accuracy of participants' performances, levels of strategy adaptation, as assessed by score improvements, showed a similar positive increase as learners were provided with increased levels of feedback information. Feedback, in general, had greater effects on strategy adaptation than no feedback. However, summative feedback alone was not associated with higher levels of adaptive adjustments.

A rather unique contribution of this study was that the self-reflective practice of making corrective adjustments after receiving formative feedback (i.e. the adaptive feedback condition) was significantly associated with the highest levels of future strategy adaptation and performance accuracy.

Self-Reflection

As was predicted from a social cognitive model of SRL, findings concerning self-reflection phase processes revealed that there were significant positive correlations among performance, strategy adaptation, self-evaluation, and self-satisfaction. The influence of different forms of feedback on adaptive self-regulatory patterns was evidenced by the microanalytic process measures.

Further empirical support was found for the self-regulatory advantages of feedback during practice pertaining to students' self-judgments. Overall, students who had observed a model and had received some form of feedback during practice reported higher post-performance self-evaluations than did students who did not receive modeling or feedback. In addition, students that received formative or adaptive feedback had significantly greater self-evaluation scores than did students who did not receive

feedback. Note that despite the low test-retest reliability (.20) for self-evaluation, it was sufficient to show group differences.

Regarding the kinds of attributional self-judgments students reported after making an error, I observed an interesting difference in the types of causal attributions made by the adaptive feedback group in comparison to the two other feedback groups. After having practiced correcting errors, students tended to make specific reference to their strategy use as responsible for mistakes. The summative and formative feedback groups tended to blame their errors on distractions, a lack of time, or limited ability. Thus, the latter groups of learners exhibited a characteristic of reactive self-regulators—a tendency to attribute errors to uncontrollable factors. In contrast, the adaptive feedback group was proactive in that they were more likely to attribute outcomes to controllable sources, namely specific strategy use (Zimmerman, 2004).

Findings regarding students' self-reactions to performance were somewhat mixed. As was true of self-evaluation, there was an overall positive linear trend in reports of self-satisfaction as the levels of support during practice increased. As predicted, students receiving more elaborative feedback (formative or adaptive feedback groups) reported higher levels of self-satisfaction with performance than students receiving no feedback. Likewise, students who had observed the strategy modeling were more satisfied with their performance than the control group.

In contrast, after making an error during the posttest phase, students in all five groups did not differ significantly from one another in the adaptive inferences they made. This self-reactive process is deemed an important factor in influencing the quality of adaptations made in response to performance feedback. Thus, this evidence did not

support the hypothesized positive linear increase in adaptive inferences as a function of strategy modeling and improved levels of feedback. However, upon closer analysis, the adaptive feedback group had the more highly calibrated adaptive inferences than did the other conditions. That is, their self-reactions as to whether they should make self-adjustments were more congruent with their actual performance accuracy. Similarly, the formative and summative feedback groups also had higher degrees of calibration than the no feedback groups, but not as strong as the adaptive feedback group. Clearly, a SRL proactive approach makes an important contribution to research on the reactive effects of feedback.

Forethought

Regarding forethought phase processes, several important self-motivation beliefs were included in this study. In accord with prior research (Bandura, 1997), perceived self-efficacy (measured before performance) was predictive of self-reflection processes, such as self-evaluation and self-satisfaction (measured after performance), as well as predictive of performance accuracy and adaptation. Unexpectedly, evidence was not found for a positive linear trend in self-efficacy as the level of learning support (instruction and feedback) increased. However, perceived self-efficacy at posttest was highest among students who had received some form of feedback during learning rather than no feedback at all. In addition, this more efficacious group of students reported less self-efficacy bias. Furthermore, the greatest observed difference in self-efficacy bias was between the adaptive feedback group and the no feedback groups. Thus, this study provides further evidence that effective self-regulators tend to be highly efficacious as well as accurate in the self-efficacy judgments.

Group mean scores for the other two self-motivation beliefs under investigation, task interest and goal orientation, did not reveal significant effects for modeling or feedback type. Although from a social cognitive perspective it is expected that effective self-regulation is associated with adaptive motivational profiles, including greater intrinsic interest and a mastery goal orientation, the present experimental paradigm may have in effect controlled for these processes to the extent that the task—which was described as a math game—was perceived as engaging and of low-stakes. It is also important to note that measurement of SRL processes was limited to only one cycle of learning. Effects on forethought phase processes and beliefs such as self-efficacy may strengthen if participants have the opportunity to go through additional cycles of self-regulated learning.

Limitations and Recommendations for Further Research

A constraint of the research design for this study was the limited duration of the individual sessions. This had implications for: (a) the amount of time afforded to instruction about the task and the strategy, (b) the number of practice problems given to students, (c) the amount of time allowed to solve each problem, and (d) to the number of tasks used for outcome measures. Future changes in these areas may lead to greater observed effects once higher levels of expertise are attained. For example, more practice trials with summative feedback might increase the performance advantages for learners in comparison to practice with no knowledge of results. A related aspect of limitation was that there was no measurement of transfer effects. Thus, the inclusion of follow-up or transfer measures would be important in future research.

Using the present experimental paradigm, more research is needed among learners of different ages or school levels. Greater numbers of learners in each condition is also needed. In addition, variations of the paradigm could involve applied, classroom contexts, as well as different kinds of mathematical tasks or tasks from different academic domains.

Educational Implications

Researchers have shown that students can be encouraged to respond to their learning and performances through self-enhancing self-regulatory processes. Teachers can and should incorporate instructional practices that foster the development of proactive self-regulatory functioning (Ley & Young, 2001; Paris & Paris, 2001; Pintrich & Schunk, 2000; Zimmerman, 2002; Zimmerman, Bonner, & Kovach, 1996).

The present study addressed several important issues, including how modeling and increasing levels of elaborative feedback dynamically affects learning, self-regulatory processes, and motivational beliefs. An important contribution of this study to existing research was that it expanded the historically limited perspective of feedback as an outcome of learning efforts to focus also on its self-reactive and motivational effects on future learning. This more comprehensive model of feedback highlighted the beneficial role of engaging students in self-reflective practice that guides their attempts to adjust strategic learning efforts based on performance feedback. The findings further demonstrate that elaboration of feedback improves adaptation of strategic efforts and performance attainments. In addition, adaptive cognitive and motivational patterns were associated with the more elaborative feedback groups. Elaborative forms of feedback led to more positive and calibrated self-judgments and self-reactions after performance self-

judgments. In line with existing research, this study demonstrated that forethought phase self-efficacy beliefs cyclically predicted these enhanced self-reflection processes.

A number of previous self-regulatory experiments have demonstrated the effectiveness of relatively brief practice with multi-phase SRL strategies on acquiring skill on *athletic* tasks such as basketball free throws and dart throwing (Cleary, Zimmerman, & Keating; Kitsantas & Zimmerman, 2002). Regarding the acquisition of *academic* skills, extensive self-regulatory intervention research has been conducted in the domain of writing (e.g. Campillo, 2005; Graham & Harris, 2005; Zimmerman & Kitsantas, 1999). However, successful interventions for enhancing self-regulatory processes have been carried out in a wide range of academic domains, including math, writing, reading comprehension, and learning-to-learn courses (Schunk & Zimmerman, 1998). Although there has been significant research on SRL development involving math learning (e.g. Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Schunk, 1981; 1983; 1996; 1998), further work is required. Therefore, this study contributes to needed research in SRL and mathematics.

Students often do not receive optimal forms of feedback. To the extent that the findings from this study are supported by existing research and future investigations, there are important implications for both the types of feedback provided to students and the ways that teachers bestow feedback. An increased understanding of how students use different forms of feedback to make strategic adjustments in learning and performance could aid in efforts to improve classroom assessment so that it empowers students. Particularly for students who are struggling academically, enhanced forms of feedback may help to improve their self-regulated learning.

Feedback that elaborates on specific errors and attends to learners' strategy modifications is likely to be more effective on enhancing learning and performance than feedback that merely connotes information about general outcomes. Prior SRL research has shown that learners benefit from an initial focus on process-oriented goals, which focus attention on task specific features or particular aspects of performing a skill (Schunk & Schwartz, 1993; Zimmerman & Kitsantas, 1997). These studies also show the comparative advantages of feedback about progress during skill development, rather than feedback merely about absolute performance levels. Other research has shown that outcome goals can have varying effects on learning and performance such that goals which are more proximal, specific, and challenging are more effective than distal, general, and easy goals (Bandura & Schunk, 1981; Locke & Latham, 1990).

Enhancements to academic feedback have implications for both *teachers'* decisions about instruction and *students'* decisions about learning. Fuchs (1995) explained that there are essentially three types of decisions that a teacher makes using feedback. First, teachers make decisions about what to teach next based on where students are relative to the instructional sequence or learning objectives. Second, while instruction is occurring, teachers use feedback to monitor student progress in terms of pace, effectiveness, and whether adjustments are required. Third, teachers use feedback to make diagnostic decisions about particular barriers that might be impeding a student's progress. Performance feedback provides essential information for a proactive learner to make changes in their self-directed efforts. Successful students use academic feedback to self-set learning goals, self-monitor, self-evaluate, and adapt their methods to learn and

self-motivate. Students are best enabled to self-regulate these processes when assessment is meaningful, interpretable, and explicitly communicates goals of learning (Fuchs, 1995).

Teachers can implement a variety of interventions and changes in classroom structure that increase the quality and frequency of feedback. For example, teachers can create more opportunities both for one-on-one feedback between student and teacher, and for peer feedback through a buddy system or group work. A fundamental implication of the SRL model for classroom practice is students' needs for frequent, guided opportunities to apply what they are learning. This translates into offering opportunities for students to practice adapting strategic approaches to specific tasks. Inquiry-based activities are powerful ways to foster such learning.

Another effectual classroom strategy is to implement frequent quizzing as a form of ongoing feedback. Teachers can experiment with different ways of communicating performance feedback, such as verbal versus written feedback, and increasing feedback on strategy use. Cleary and Zimmerman (2004) have described the Self-Regulation Empowerment Program (SREP), a school-based one-on-one intervention, as utilizing a graphing chart as a key feedback intervention tool because multiple self-regulatory processes involving forethought, performance control, and self-reflection could be affected simultaneously with the support of a SRL coach. Another school-based intervention, the Fostering Communities of Learners (FCL) instructional program (Brown & Campione, 1996), devised ways to modify both the development and debriefing of quizzes and tests so that students had explicit opportunities for self-reflection about performance feedback.

There are a variety of methods for integrating assessment with instruction, including mastery learning, curriculum-based measurement, behavioral assessment, and performance assessment (Fuchs, 1995; Zimmerman & DiBenedetto, 2008). Each approach has strengths and limitations, yet continue to evolve as teachers assimilate different approaches or develop specific methods. Optimistically, there is widespread appreciation of the need for nurturing students' self-regulatory processes and motivational beliefs. Going forward, it is necessary to develop greater understanding of how these self-regulatory processes and motivational beliefs can be enhanced through the self-reflective practice with adaptive feedback use.

APPENDIX A

CONSENT LETTER

NEW YORK CITY
COLLEGE OF TECHNOLOGY
THE CITY UNIVERSITY OF NEW YORK
300 JAY STREET, BROOKLYN, NY 11201-1909

Dear Student:

My name is Adam Moylan, and I work in the SEEK Department of the New York City College of Technology. I am also a student in the PhD Educational Psychology Program at the Graduate School and University Center of CUNY. I am asking that you please consider participating in a research study by coming to a one-hour session that involves learning a new numbers game.

All information gathered will be kept strictly confidential, and will be stored in a locked file cabinet. A summary of the overall results of this study may be presented to educational professionals. No individual student information will be shared.

If you choose to participate, you do not have to answer any question that you feel uncomfortable about, and you can stop your participation at any time. Your choice to participate or not participate does NOT negate your receiving of the monetary incentive.

However, your participation is highly valuable. You will contribute important insight for educators and researchers about learning and mathematics instruction. Furthermore, you may benefit from your involvement in the math tasks and responses to various questions.

If you want a copy of the completed study, I can get a copy to you when it is done. If you have any questions about this project, you can contact me at (xxx) xxx-xxxx or xxx@email.com. If you have any questions about your rights as a participant in this study, you can contact Professor Fred Nalven, IRB Administrator, The New York City College of Technology, (212) 260-5081.

Thank you for your participation in this study. I will give you a copy of this form to take with you.

I agree to participate in this study [circle one]: Yes No

______________________________ ________

Participant’s signature Date

______________________________ ________

Investigator’s signature Date

APPENDIX B

DEMOGRAPHIC SHEET

All responses that you volunteer below will help us to describe the study sample.

Age:

Gender:

Primary ethnicity:

Primary language:

Parent occupations:

College major:

Current math course:

APPENDIX C

MATH TASK INSTRUCTIONS

Objective:

Use addition, subtraction, multiplication, and division to combine the numbers in the array to come as close as you can to the target number. Every task has possible solutions that equal the target number exactly.

Criteria:

- Use each array number only once.
- You do not have to use all array numbers.
- Only use positive, whole numbers.
- Write your final solution following the correct Order of Operations:
    1. First, solve operations within parenthesis
    2. Next, from left to right do any multiplication or division
    3. Last, from left to right do any addition or subtraction

Example task:

Array: 3 , 4 , 1 , 6 , 9 , 2 Target: 225

Example final answers: ((6 * 4) + 1) * 9 = 225

4 (9 * 6 + 2) + 1 = 225

APPENDIX D

MATH TASK STRATEGY

The goal is to breakdown large numbers into parts so that we can combine the array numbers to equal the target number (225).

1. The target number is the biggest number, so one trick is to divide it with a large number from the array (such as 9). Write the target number in terms of its part by multiplying the divisor and the dividend, and then add any remainder in a temporary solution that equals the target number.
2. Cross-off the array numbers used in your temporary solution. If any numbers are not in the array (e.g. 25), try similarly to break them down by dividing with another large array number (e.g. 6). Again, write out the parts and cross-off the used array numbers.
3. Combine the array numbers from each step in a final solution that equals the target number and check your final solution.
4. If you are ever stuck, go back to step 1 and divide the target number by another large array number and repeat each step as necessary.

APPENDIX E

EXAMPLE POSTTEST TASK AND SCALES

A1. How confident are you that you can find a successful solution to this problem? (*Circle the number below that best reflects your response*).

Definitely not confident									Extremely confident
1	2	3	4	5	6	7	8	9	10

B1. Use only the array numbers and basic arithmetic operations to arrive or come as close as possible to the target answer.

Array: 5, 9, 3, 8, 5, 3 Target: 624

C1. After attempting to solve the problem, how confident are you that your answer is correct? (*Circle the number below that best reflects your response*).

Definitely not confident									Extremely confident
1	2	3	4	5	6	7	8	9	10

D1. If your answer to this problem is wrong, why do you think you did not do better? (*Use the space below to provide your response*).

E1. If your answer to this problem is wrong, would you change your method or approach? (*Circle one*).

Yes No

F1. How satisfied are you with your problem solving effort? (Circle the number below that best reflects your response).

Not at all satisfied									Extremely satisfied
1	2	3	4	5	6	7	8	9	10

Circle the number that best reflects your response to each item.

G1. How anxious do you feel about this math task?

Extremely anxious									Not at all anxious
1	2	3	4	5	6	7	8	9	10

H1. Compared to other math tasks you have done, how much did you enjoy solving this problem?

Much less									Much more
1	2	3	4	5	6	7	8	9	10

I1. It is important to me to show others that I am good at this task.

Not at all true									Completely true
1	2	3	4	5	6	7	8	9	10

J1. It is important to me that I look smart compared to others on this math task.

Not at all true									Completely true
1	2	3	4	5	6	7	8	9	10

K1. It is important to me to improve my skills on this math task.

Not at all true									Completely true
1	2	3	4	5	6	7	8	9	10

L1. It is important to me that I keep others from thinking I am not smart on this math task.

Not at all true									Completely true
1	2	3	4	5	6	7	8	9	10

M1. It is important to me to thoroughly understand how to solve this math task.

Not at all true									Completely true
1	2	3	4	5	6	7	8	9	10

N1. It is important to me that I avoid looking like I have trouble doing the work on this math task.

Not at all true									Completely true
1	2	3	4	5	6	7	8	9	10

APPENDIX F

RESEARCH PROTOCOL SCRIPTS

Control Group (Group 1)

Instruction Phase

GREET STUDENT. GIVE THEM THE CONSENT FORM TO READ. ASK FOR STUDENT TO PROVIDE SIGNATURE IF THEY WOULD LIKE TO PARTICIPATE. IF THE STUDENT HAS GIVEN CONSENT, HAVE THEM COMPLETE THE DEMOGRAPHIC SHEET. LOG THE STUDENT'S NAME AND THE DATE AND TIME OF SESSION.

ONCE THE STUDENT IS READY, GIVE THEM THE MATH TASK INSTRUCTION SHEET.

"I am going to ask you to work on some unique math task problems. The objective of the task is to combine the numbers in the array on the left using the basic arithmetic operations of addition, subtraction, multiplication, and division to come as close as you can to the target number on the right. Every task has possible solutions that equal the target number exactly.

The criteria for the math task are that you:

1) Use each array number only once.

2) You do not have to use all array numbers.

3) Only use positive, whole numbers.

4) Write your final solution following the correct Order of Operations:

a) First, solve operations within parenthesis

b) Next, from left to right, do any multiplication or division

c) Last, from left to right, do any addition or subtraction

For example, the array of numbers is 9, 4, 1, 6, 3, and 2, and the target number to reach is 225. Given the array, how can they be arranged into an equation that equals the target number? Two example answer are provided here. For example, six multiplied by 4 is 24, and plus 1 is 25, and then that multiplied by 9 is equal to 225.
Are there any questions?"

HAND STUDENT THE PRETEST PROBLEM SHEET [3, 6, 2, 4, 4, 2; 199].

"Here is an example problem for you to try to solve. You will be given six minutes to come up with an answer, and I will let you know when there is just one minute left. If you finish early, let me know as soon as you do."

SET TIMER FOR 5 MINS.
GIVE 1 MINUTE WARNING AFTER 5 MINUTES.

"There's one minute left so start to write out your best answer for an equation."

MONITOR THE CLOCK/WATCH AND STOP STUDENT AFTER 1 MIN.

WHEN THE STUDENT IS FINISHED, CALCULATE THEIR ANSWER AND TELL THEM WHETHER IT IS RIGHT OR WRONG [I.E. RESPONSE EQUALS TARGET]. GIVE CORRECTIVE FEEDBACK FOR ERRORS IN FOLLOWING THE RULES OF THE MATH TASK.

Learning Phase

GIVE STUDENTS PROBLEM SHEET # 1.

"Now, I am going to give you 3 more of this type of problem for practice before I test you on 2 final problems. You will have six minutes, including the one-minute warning, to do your best on each problem. Again, if you finish early, let me know as soon as you do."

SET TIMER.

GIVE 1 MINUTE WARNING AFTER 5 MINUTES.

"There's one minute left so start to write out your best answer for an equation."

WHEN STUDENT IS DONE OR THE TIMER HAS RUNG, HAND THEM THE SECOND PROBLEM SHEET. ASK STUDENT TO SOLVE THE PROBLEM. SET THE TIMER FOR 5 MINS. GIVE 1 MIN. WARNING.

REPEAT FOR PROBLEM SHEET #3.

TAKE AWAY THE TASK INSTRUCTIONS AND STRATEGY SHEET.

Posttest Phase

"Now that you have had some practice with these problems, I will give you two more problems to see how well you have learned to solve them. Before solving the first problem, I want you to look it over and then respond to the item before the problem. After solving the problem, I want you to respond to all of the questionnaire items that follow. I will then ask that you do the same for the second problem. Are there any questions? You may begin when you are ready."

MONITOR THAT STUDENT FIRST ANSWERS ITEM 1. IF NECESSARY, PROMPT STUDENT AND READ THE QUESTION.

"How confident are you that you can find a successful solution to this problem?"

SET THE TIMER FOR 5 MINS. AFTER STUDENT RESPONDS TO ITEM 1. GIVE 1 MIN. WARNING.

CHECK THAT THE STUDENT RESPONDS TO ALL ITEMS. WHEN STUDENT IS READY, HAND THEM THE SECOND (LAST) POSTTEST PROBLEM SHEET. ASK THEM TO COMPLETE IT, ALSO.

Wrap-up

1. WHEN STUDENT IS FINISHED, COLLECT ALL FORMS AND THANK THE STUDENT FOR THEIR PARTICIPATION.

2. LOG THE END TIME AND FILE ALL DATA IN ITS RESPECTIVE FILE FOLDERS.
3. SIGN COMPLETION FORMS—1 FOR STUDENT AND 1 FOR FILES.
4. IF THE INCENTIVE $ IS AVAILABLE, DISTRIBUTE IT AFTER STUDENT SIGNS THE DISBURSEMENT RECEIPTS (1 FOR STUDENT AND 1 FOR FILES). IF $ IS NOT AVAILABLE, ARRANGE FOR STUDENT TO COME BACK AT ANOTHER TIME TO A236.
5. DEBRIEF STUDENT. EMPHASIZE THE IMPORTANCE OF NOT DISCUSSING THE STUDY WITH ANYONE, ESPECIALLY INCLUDING THIS NUMBER GAME.
6. ASK FOR FEEDBACK AND QUESTIONS. THANK THE STUDENT FOR THEIR HELP.

Strategy Group (Group 2)

Instruction Phase

GREET STUDENT. GIVE THEM THE CONSENT FORM TO READ. ASK FOR STUDENT TO PROVIDE SIGNATURE IF THEY WOULD LIKE TO PARTICIPATE. IF THE STUDENT HAS GIVEN CONSENT, HAVE THEM COMPLETE THE DEMOGRAPHIC SHEET. LOG THE STUDENT'S NAME AND THE DATE AND TIME OF SESSION.

ONCE THE STUDENT IS READY, GIVE THEM THE MATH TASK INSTRUCTION SHEET.

"I am going to ask you to work on some unique math task problems. The objective of the task is to combine the numbers in the array on the left using the basic arithmetic operations of addition, subtraction, multiplication, and division to come as close as you can to the target number on the right. Every task has possible solutions that equal the target number exactly.

The criteria for the math task are that you:

1) Use each array number only once.

2) You do not have to use all array numbers.

3) Only use positive, whole numbers.

4) Write your final solution following the correct Order of Operations:

a) First, solve operations within parenthesis

b) Next, from left to right, do any multiplication or division

c) Last, from left to right, do any addition or subtraction

For example, the array of numbers is 9, 4, 1, 6, 3, and 2, and the target number to reach is 225. Given the array, how can they be arranged into an equation that equals the target number? Two example answer are provided here. For example, six multiplied by 4 is 24, and plus 1 is 25, and then that multiplied by 9 is equal to 225.
Are there any questions?"

HAND STUDENT THE PRETEST PROBLEM SHEET [3, 6, 2, 4, 4, 2; 199].

"Here is an example problem for you to try to solve. You will be given six minutes to come up with an answer, and I will let you know when there is just one minute left. If you finish early, let me know as soon as you do."

SET TIMER FOR 5 MINS.
GIVE 1 MINUTE WARNING AFTER 5 MINUTES.

"There's one minute left so start to write out your best answer for an equation."

MONITOR THE CLOCK/WATCH AND STOP STUDENT AFTER 1 MIN.
WHEN THE STUDENT IS FINISHED, CALCULATE THEIR ANSWER AND TELL THEM WHETHER IT IS RIGHT OR WRONG [I.E. RESPONSE EQUALS TARGET]. GIVE CORRECTIVE FEEDBACK FOR ERRORS IN FOLLOWING THE RULES OF THE MATH TASK.

***HAND THE STUDENT THE STRATEGY SHEET.

"Before I ask you to practice 3 problems on your own, I am going to show you a strategy for solving them using the first task I showed you. There are several steps to the strategy:

The goal is to breakdown large numbers into parts so that we can combine the array numbers to equal the target number (225).

1. *The target number is the biggest number, so one trick is to divide it with a large number from the array (such as 9). Write the target number in terms of its part by multiplying the divisor and the dividend, and then add any remainder in a temporary solution that equals the target number.*
2. *Cross-off the array numbers used in your temporary solution. If any numbers are not in the array (e.g. 25), try similarly to break them down by dividing with another large array number (e.g. 6). Again, write out the parts and cross-off the used array numbers.*
3. *Combine the array numbers from each step in a final solution that equals the target number and check your final solution.*
4. *If you are ever stuck, go back to step 1 and divide the target number by another large array number and repeat each step as necessary."*

WRITE OUT ALL COMPUTATIONS AND FORMULAS AT EACH STEP.

CLEARLY WRITE OUT THE ANSWER FORMULA AND THE CHECKING/COMPUTATION PROCESS.

"Are there any questions?"

Learning Phase

GIVE STUDENTS PROBLEM SHEET # 1.

"Now, I am going to give you 3 more of this type of problem for practice before I test you on 2 final problems. You will have six minutes, including the one-minute warning, to do your best on each problem. Again, if you finish early, let me know as soon as you do."

*REMIND STRATEGY GROUP STUDENTS TO USE THE STRATEGIES.

****"Remember to use the steps on the strategy sheet to help you solve these problems."*

SET TIMER.

"There's one minute left so start to write out your best answer for an equation."

WATCH WATCH/CLOCK AND STOP STUDENT AFTER 1 MIN.

WHEN THE STUDENT IS FINISHED. CALCULATE THEIR ANSWER AND TELL THEM WHETHER IT IS RIGHT OR WRONG [I.E. RESPONSE EQUALS TARGET].

REPEAT FOR PROBLEM SHEET #3.

TAKE AWAY THE TASK INSTRUCTIONS AND STRATEGY SHEET.

Posttest Phase

"Now that you have had some practice with these unique problems, I will give you two more problems to see how well you have learned to solve them. Before solving the first problem, I want you to look it over and then respond to the item before the problem. After solving the problem, I want you to respond to all of the questionnaire items that follow. I will then ask that you do the same for the second problem. Are there any questions? You may begin when you are ready."

MONITOR THAT STUDENT FIRST ANSWERS ITEM 1. IF NECESSARY, PROMPT STUDENT AND READ THE QUESTION.

"How confident are you that you can find a successful solution to this problem?"

SET THE TIMER FOR 5 MINS. AFTER STUDENT RESPONDS TO ITEM 1. GIVE 1 MIN. WARNING.

CHECK THAT THE STUDENT RESPONDS TO ALL ITEMS. WHEN STUDENT IS READY, HAND THEM THE SECOND (LAST) POSTTEST PROBLEM SHEET. ASK THEM TO COMPLETE IT, ALSO.

Wrap-up

1. WHEN STUDENT IS FINISHED, COLLECT ALL FORMS AND THANK THE STUDENT FOR THEIR PARTICIPATION.
2. LOG THE END TIME AND FILE ALL DATA IN ITS RESPECTIVE FILE FOLDERS.

3. SIGN COMPLETION FORMS—1 FOR STUDENT AND 1 FOR FILES.
4. IF THE INCENTIVE $ IS AVAILABLE, DISTRIBUTE IT AFTER STUDENT SIGNS THE DISBURSEMENT RECEIPTS (1 FOR STUDENT AND 1 FOR FILES). IF $ IS NOT AVAILABLE, ARRANGE FOR STUDENT TO COME BACK AT ANOTHER TIME TO A236.
5. DEBRIEF STUDENT. EMPHASIZE THE IMPORTANCE OF NOT DISCUSSING THE STUDY WITH ANYONE, ESPECIALLY INCLUDING THIS NUMBER GAME.
6. ASK FOR FEEDBACK AND QUESTIONS. THANK THE STUDENT FOR THEIR HELP.

Summative Feedback Group (Group 3)

Instruction Phase

GREET STUDENT. GIVE THEM THE CONSENT FORM TO READ. ASK FOR STUDENT TO PROVIDE SIGNATURE IF THEY WOULD LIKE TO PARTICIPATE. IF THE STUDENT HAS GIVEN CONSENT, HAVE THEM COMPLETE THE DEMOGRAPHIC SHEET. LOG THE STUDENT'S NAME AND THE DATE AND TIME OF SESSION.

ONCE THE STUDENT IS READY, GIVE THEM THE MATH TASK INSTRUCTION SHEET.

"I am going to ask you to work on some unique math task problems. The objective of the task is to combine the numbers in the array on the left using the basic arithmetic operations of addition, subtraction, multiplication, and division to come as close as you can to the target number on the right. Every task has possible solutions that equal the target number exactly.

The criteria for the math task are that you:

1) Use each array number only once.

2) You do not have to use all array numbers.

3) Only use positive, whole numbers.

4) Write your final solution following the correct Order of Operations:

a) First, solve operations within parenthesis

b) Next, from left to right, do any multiplication or division

c) Last, from left to right, do any addition or subtraction

For example, the array of numbers is 9, 4, 1, 6, 3, and 2, and the target number to reach is 225. Given the array, how can they be arranged into an equation that equals the target number? Two example answer are provided here. For example, six multiplied by 4 is 24, and plus 1 is 25, and then that multiplied by 9 is equal to 225.

Are there any questions?"

HAND STUDENT THE PRETEST PROBLEM SHEET [3, 6, 2, 4, 4, 2; 199].

"Here is an example problem for you to try to solve. You will be given six minutes to come up with an answer, and I will let you know when there is just one minute left. If you finish early, let me know as soon as you do."

SET TIMER FOR 5 MINS.

GIVE 1 MINUTE WARNING AFTER 5 MINUTES.

"There's one minute left so start to write out your best answer for an equation."

MONITOR THE CLOCK/WATCH AND STOP STUDENT AFTER 1 MIN.

WHEN THE STUDENT IS FINISHED, CALCULATE THEIR ANSWER AND TELL THEM WHETHER IT IS RIGHT OR WRONG [I.E. RESPONSE EQUALS TARGET].

GIVE CORRECTIVE FEEDBACK FOR ERRORS IN <u>FOLLOWING THE RULES</u> OF THE MATH TASK.

***HAND THE STUDENT THE STRATEGY SHEET.

"Before I ask you to practice 3 problems on your own, I am going to show you a strategy for solving them using the first task I showed you. There are several steps to the strategy:

The goal is to breakdown large numbers into parts so that we can combine the array numbers to equal the target number (225).

1. *The target number is the biggest number, so one trick is to divide it with a large number from the array (such as 9). Write the target number in terms of its part by multiplying the divisor and the dividend, and then add any remainder in a temporary solution that equals the target number.*
2. *Cross-off the array numbers used in your temporary solution. If any numbers are not in the array (e.g. 25), try similarly to break them down by dividing with another large array number (e.g. 6). Again, write out the parts and cross-off the used array numbers.*
3. *Combine the array numbers from each step in a final solution that equals the target number and check your final solution.*
4. *If you are ever stuck, go back to step 1 and divide the target number by another large array number and repeat each step as necessary."*

WRITE OUT ALL COMPUTATIONS AND FORMULAS AT EACH STEP.

CLEARLY WRITE OUT THE ANSWER FORMULA AND THE CHECKING/COMPUTATION PROCESS.

"Are there any questions?"

Learning Phase

GIVE STUDENTS PROBLEM SHEET # 1.

"Now, I am going to give you 3 more of this type of problem for practice before I test you on 2 final problems. You will have six minutes, including the one-minute warning, to do your best on each problem. Again, if you finish early, let me know as soon as you do."

REMIND STRATEGY GROUP STUDENTS TO USE THE STRATEGY.

****"Remember to use the steps on the strategy sheet to help you solve these problems."*

SET TIMER.

"There's one minute left so start to write out your best answer for an equation."

WATCH WATCH/CLOCK AND STOP STUDENT AFTER 1 MIN.

***WHEN THE STUDENT IS DONE OR TIME IS UP, TAKE THEIR TASK FORM AND CALCULATE THE ANSWER TO THEIR FORMULA AS IT IS WRITTEN. SHOW TO THE STUDENT A COMPARISON OF THAT ANSWER TO THE TARGET NUMBER.

HAND THEM THE SECOND PROBLEM SHEET. ASK STUDENT TO SOLVE THE PROBLEM. SET THE TIMER FOR 5 MINS. GIVE 1 MIN WARNING.

WHEN STUDENT IS FINISHED, AGAIN CALCULATE THEIR ANSWER AND SHOW THE RESULT IN COMPARISON TO THE TARGET.

REPEAT FOR PROBLEM SHEET #3.

TAKE AWAY THE TASK INSTRUCTIONS AND STRATEGY SHEET.

Posttest Phase

"Now that you have had some practice with these unique problems, I will give you two more problems to see how well you have learned to solve them. Before solving the first problem, I want you to look it over and then respond to the item before the problem. After solving the problem, I want you to respond to all of the questionnaire items that follow. I will then ask that you do the same for the second problem. Are there any questions? You may begin when you are ready."

MONITOR THAT STUDENT FIRST ANSWERS ITEM 1. IF NECESSARY, PROMPT STUDENT AND READ THE QUESTION.

"How confident are you that you can find a successful solution to this problem?"

SET THE TIMER FOR 5 MINS. AFTER STUDENT RESPONDS TO ITEM 1. GIVE 1 MIN. WARNING.

CHECK THAT THE STUDENT RESPONDS TO ALL ITEMS. WHEN STUDENT IS READY, HAND THEM THE SECOND (LAST) POSTTEST PROBLEM SHEET. ASK THEM TO COMPLETE IT, ALSO.

Wrap-up

1. WHEN STUDENT IS FINISHED, COLLECT ALL FORMS AND THANK THE STUDENT FOR THEIR PARTICIPATION.
2. LOG THE END TIME AND FILE ALL DATA IN ITS RESPECTIVE FILE FOLDERS.
3. SIGN COMPLETION FORMS—1 FOR STUDENT AND 1 FOR FILES.
4. IF THE INCENTIVE $ IS AVAILABLE, DISTRIBUTE IT AFTER STUDENT SIGNS THE DISBURSEMENT RECEIPTS (1 FOR STUDENT AND 1 FOR FILES). IF $ IS NOT AVAILABLE, ARRANGE FOR STUDENT TO COME BACK AT ANOTHER TIME TO A236.
5. DEBRIEF STUDENT. EMPHASIZE THE IMPORTANCE OF NOT DISCUSSING THE STUDY WITH ANYONE, ESPECIALLY INCLUDING THIS NUMBER GAME.
6. ASK FOR FEEDBACK AND QUESTIONS. THANK THE STUDENT FOR THEIR HELP.

Formative Feedback Group (Group 4)

Instruction Phase

GREET STUDENT. GIVE THEM THE CONSENT FORM TO READ. ASK FOR STUDENT TO PROVIDE SIGNATURE IF THEY WOULD LIKE TO PARTICIPATE.

IF THE STUDENT HAS GIVEN CONSENT, HAVE THEM COMPLETE THE DEMOGRAPHIC SHEET. LOG THE STUDENT'S NAME AND THE DATE AND TIME OF SESSION.

ONCE THE STUDENT IS READY, GIVE THEM THE MATH TASK INSTRUCTION SHEET.

"I am going to ask you to work on some unique math task problems. The objective of the task is to combine the numbers in the array on the left using the basic arithmetic operations of addition, subtraction, multiplication, and division to come as close as you can to the target number on the right. Every task has possible solutions that equal the target number exactly.

The criteria for the math task are that you:

1) Use each array number only once.

2) You do not have to use all array numbers.

3) Only use positive, whole numbers.

4) Write your final solution following the correct Order of Operations:

a) First, solve operations within parenthesis

b) Next, from left to right, do any multiplication or division

c) Last, from left to right, do any addition or subtraction

For example, the array of numbers is 9, 4, 1, 6, 3, and 2, and the target number to reach is 225. Given the array, how can they be arranged into an equation that equals the target number? Two example answer are provided here. For example, six multiplied by 4 is 24, and plus 1 is 25, and then that multiplied by 9 is equal to 225.

Are there any questions?"

HAND STUDENT THE PRETEST PROBLEM SHEET [3, 6, 2, 4, 4, 2; 199].

"Here is an example problem for you to try to solve. You will be given six minutes to come up with an answer, and I will let you know when there is just one minute left. If you finish early, let me know as soon as you do."

SET TIMER FOR 5 MINS.

GIVE 1 MINUTE WARNING AFTER 5 MINUTES.

"There's one minute left so start to write out your best answer for an equation."

MONITOR THE CLOCK/WATCH AND STOP STUDENT AFTER 1 MIN.

WHEN THE STUDENT IS FINISHED, CALCULATE THEIR ANSWER AND TELL THEM WHETHER IT IS RIGHT OR WRONG [I.E. RESPONSE EQUALS TARGET]. GIVE CORRECTIVE FEEDBACK FOR ERRORS IN <u>FOLLOWING THE RULES</u> OF THE MATH TASK.

***HAND THE STUDENT THE STRATEGY SHEET.

"Before I ask you to practice 3 problems on your own, I am going to show you a strategy for solving them using the first task I showed you. There are several steps to the strategy:

The goal is to breakdown large numbers into parts so that we can combine the array numbers to equal the target number (225).

1. *The target number is the biggest number, so one trick is to divide it with a large number from the array (such as 9). Write the target number in terms of its part by multiplying the divisor and the dividend, and then add any remainder in a temporary solution that equals the target number.*

2. *Cross-off the array numbers used in your temporary solution. If any numbers are not in the array (e.g. 25), try similarly to break them down by dividing with another large array number (e.g. 6). Again, write out the parts and cross-off the used array numbers.*

3. *Combine the array numbers from each step in a final solution that equals the target number and check your final solution.*

4. *If you are ever stuck, go back to step 1 and divide the target number by another large array number and repeat each step as necessary."*

WRITE OUT ALL COMPUTATIONS AND FORMULAS AT EACH STEP.

CLEARLY WRITE OUT THE ANSWER FORMULA AND THE CHECKING/COMPUTATION PROCESS.

"Are there any questions?"

Learning Phase

GIVE STUDENTS PROBLEM SHEET # 1.

"Now, I am going to give you 3 more of this type of problem for practice before I test you on 2 final problems. You will have six minutes, including the one-minute warning, to do your best on each problem. Again, if you finish early, let me know as soon as you do."

*REMIND STRATEGY GROUP STUDENTS TO USE THE STRATEGIES.

***"Remember to use the steps on the strategy sheet to help you solve these problems."*

SET TIMER FOR 5 MINS.

"There's one minute left so start to write out your best answer for an equation."

WATCH WATCH/CLOCK AND STOP STUDENT AFTER 1 MIN.

*WHEN THE STUDENT IS DONE OR TIME IS UP, TAKE THEIR TASK FORM, CALCULATE THE ANSWER USING THEIR FORMULA, AND COMPARE THAT TO THE TARGET NUMBER.

***IN ADDITION, IDENTIFY THE SOURCE OF NO MORE THAN 2 ERRORS.

IF THERE ARE NO ERRORS, TELL THE STUDENT THAT THEY FOLLOWED ALL THE STEPS OF THE STRATEGY CORRECTLY AND ASK THEM TO TRY ANOTHER PROBLEM.

HAND THEM THE SECOND PROBLEM SHEET. ASK STUDENT TO SOLVE THE PROBLEM. SET THE TIMER FOR 5 MINS. GIVE 1 MIN. WARNING.

REPEAT FOR PROBLEM SHEET #3.

TAKE AWAY THE TASK INSTRUCTIONS AND STRATEGY SHEET.

Posttest Phase

"Now that you have had some practice with these unique problems, I will give you two more problems to see how well you have learned to solve them. Before solving the first problem, I want you to look it over and then respond to the item before the problem. After solving the problem, I want you to respond to all of the questionnaire items that follow. I will then ask that you do the same for the second problem. Are there any questions? You may begin when you are ready."

SET THE TIMER FOR 5 MINS. AFTER STUDENT RESPONDS TO ITEM 1. GIVE 1 MIN. WARNING.

CHECK THAT THE STUDENT RESPONDS TO ALL ITEMS. WHEN STUDENT IS READY, HAND THEM THE SECOND (LAST) POSTTEST PROBLEM SHEET. ASK THEM TO COMPLETE IT, ALSO.

Wrap-up

1. WHEN STUDENT IS FINISHED, COLLECT ALL FORMS AND THANK THE STUDENT FOR THEIR PARTICIPATION.
2. LOG THE END TIME AND FILE ALL DATA IN ITS RESPECTIVE FILE FOLDERS.
3. SIGN COMPLETION FORMS—1 FOR STUDENT AND 1 FOR FILES.
4. IF THE INCENTIVE $ IS AVAILABLE, DISTRIBUTE IT AFTER STUDENT SIGNS THE DISBURSEMENT RECEIPTS (1 FOR STUDENT AND 1 FOR FILES). IF $ IS NOT AVAILABLE, ARRANGE FOR STUDENT TO COME BACK AT ANOTHER TIME TO A236.
5. DEBRIEF STUDENT. EMPHASIZE THE IMPORTANCE OF NOT DISCUSSING THE STUDY WITH ANYONE, ESPECIALLY INCLUDING THIS NUMBER GAME.
6. ASK FOR FEEDBACK AND QUESTIONS. THANK THE STUDENT FOR THEIR HELP.

Adaptive Feedback Group (Group 5)

Instruction Phase

GREET STUDENT. GIVE THEM THE CONSENT FORM TO READ. ASK FOR STUDENT TO PROVIDE SIGNATURE IF THEY WOULD LIKE TO PARTICIPATE. IF THE STUDENT HAS GIVEN CONSENT, HAVE THEM COMPLETE THE DEMOGRAPHIC SHEET. LOG THE STUDENT'S NAME AND THE DATE AND TIME OF SESSION.

ONCE THE STUDENT IS READY, GIVE THEM THE MATH TASK INSTRUCTION SHEET.

"I am going to ask you to work on some unique math task problems. The objective of the task is to combine the numbers in the array on the left using the basic arithmetic operations of addition, subtraction, multiplication, and division to come as close as you can to the target number on the right. Every task has possible solutions that equal the target number exactly.

The criteria for the math task are that you:

1) Use each array number only once.

2) You do not have to use all array numbers.

3) Only use positive, whole numbers.

4) Write your final solution following the correct Order of Operations:

a) First, solve operations within parenthesis

b) Next, from left to right, do any multiplication or division

c) Last, from left to right, do any addition or subtraction

For example, the array of numbers is 9, 4, 1, 6, 3, and 2, and the target number to reach is 225. Given the array, how can they be arranged into an equation that equals the target number? Two example answer are provided here. For example, six multiplied by 4 is 24, and plus 1 is 25, and then that multiplied by 9 is equal to 225.

Are there any questions?"

HAND STUDENT THE PRETEST PROBLEM SHEET [3, 6, 2, 4, 4, 2; 199].

"Here is an example problem for you to try to solve. You will be given six minutes to come up with an answer, and I will let you know when there is just one minute left. If you finish early, let me know as soon as you do."

SET TIMER FOR 5 MINS.

GIVE 1 MINUTE WARNING AFTER 5 MINUTES.

"There's one minute left so start to write out your best answer for an equation."

MONITOR THE CLOCK/WATCH AND STOP STUDENT AFTER 1 MIN.

WHEN THE STUDENT IS FINISHED, CALCULATE THEIR ANSWER AND TELL THEM WHETHER IT IS RIGHT OR WRONG [I.E. RESPONSE EQUALS TARGET]. GIVE CORRECTIVE FEEDBACK FOR ERRORS IN <u>FOLLOWING THE RULES</u> OF THE MATH TASK.

***HAND THE STUDENT THE STRATEGY SHEET.

"Before I ask you to practice 3 problems on your own, I am going to show you a strategy for solving them using the first task I showed you. There are several steps to the strategy:

The goal is to breakdown large numbers into parts so that we can combine the array numbers to equal the target number (225).

1. *The target number is the biggest number, so one trick is to divide it with a large number from the array (such as 9). Write the target number in terms of its part by multiplying the divisor and the dividend, and then add any remainder in a temporary solution that equals the target number.*
2. *Cross-off the array numbers used in your temporary solution. If any numbers are not in the array (e.g. 25), try similarly to break them down by dividing with another large array number (e.g. 6). Again, write out the parts and cross-off the used array numbers.*
3. *Combine the array numbers from each step in a final solution that equals the target number and check your final solution.*
4. *If you are ever stuck, go back to step 1 and divide the target number by another large array number and repeat each step as necessary."*

WRITE OUT ALL COMPUTATIONS AND FORMULAS AT EACH STEP.

CLEARLY WRITE OUT THE ANSWER FORMULA AND THE CHECKING/COMPUTATION PROCESS.

"Are there any questions?"

Learning Phase

GIVE STUDENTS PROBLEM SHEET # 1.

"Now, I am going to give you 3 more of this type of problem for practice before I test you on 2 final problems. You will have six minutes, including the one-minute warning, to do your best on each problem. Again, if you finish early, let me know as soon as you do."

*REMIND STRATEGY GROUP STUDENTS TO USE THE STRATEGIES.

****"Remember to use the steps on the strategy sheet to help you solve these problems."*

SET TIMER FOR 5 MINS.

"There's one minute left so start to write out your best answer for an equation."

WATCH WATCH/CLOCK AND STOP STUDENT AFTER 1 MIN.

1) WHEN THE STUDENT IS DONE OR THE TIMER HAS RUNG, TAKE THEIR TASK FORM, CALCULATE THE ANSWER USING THEIR FORMULA, AND COMPARE THAT TO THE TARGET NUMBER.

2) IN ADDITION, IDENTIFY THE SOURCE OF ERRORS (NO MORE THAN 2).

***3) HAVE STUDENT SELF-CORRECT PROBLEM AND SELF-VERBALIZE.

****"Try to correct this problem and explain what you are doing differently."*

RESPOND TO THE STUDENT BY LETTING THEM KNOW WHETHER THEY ARE ON THE RIGHT OR WRONG TRACK.

IF THERE ARE NO ERRORS, TELL THE STUDENT THAT THEY FOLLOWED ALL THE STEPS OF THE STRATEGY CORRECTLY AND ASK THEM TO TRY ANOTHER PROBLEM.

HAND THEM THE SECOND PROBLEM SHEET. ASK STUDENT TO SOLVE THE PROBLEM. SET THE TIMER FOR 5 MINS. GIVE 1 MIN. WARNING.

REPEAT FOR PROBLEM SHEET #3.

TAKE AWAY THE TASK INSTRUCTIONS AND STRATEGY SHEET.

Posttest Phase

"Now that you have had some practice with these unique problems, I will give you two more problems to see how well you have learned to solve them. Before solving the first problem, I want you to look it over and then respond to the item before the problem. After solving the problem, I want you to respond to all of the questionnaire items that follow. I will then ask that you do the same for the second problem. Are there any questions? You may begin when you are ready."

SET THE TIMER FOR 5 MINS. AFTER STUDENT RESPONDS TO ITEM 1. GIVE 1 MIN. WARNING.

CHECK THAT THE STUDENT RESPONDS TO ALL ITEMS. WHEN STUDENT IS READY, HAND THEM THE SECOND (LAST) POSTTEST PROBLEM SHEET. ASK THEM TO COMPLETE IT, ALSO.

Wrap-up

1. WHEN STUDENT IS FINISHED, COLLECT ALL FORMS AND THANK THE STUDENT FOR THEIR PARTICIPATION.
2. LOG THE END TIME AND FILE ALL DATA IN ITS RESPECTIVE FILE FOLDERS.
3. SIGN COMPLETION FORMS—1 FOR STUDENT AND 1 FOR FILES.
4. IF THE INCENTIVE $ IS AVAILABLE, DISTRIBUTE IT AFTER STUDENT SIGNS THE DISBURSEMENT RECEIPTS (1 FOR STUDENT AND 1 FOR FILES). IF $ IS NOT AVAILABLE, ARRANGE FOR STUDENT TO COME BACK AT ANOTHER TIME TO A236.
5. DEBRIEF STUDENT. EMPHASIZE THE IMPORTANCE OF NOT DISCUSSING THE STUDY WITH ANYONE, ESPECIALLY INCLUDING THIS NUMBER GAME.
6. ASK FOR FEEDBACK AND QUESTIONS. THANK THE STUDENT FOR THEIR HELP.

REFERENCES

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84*, 261-271.

Ames, C., & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivation process. *Journal of Educational Psychology, 80,* 260-267.

Baldi, S., Jin, Y., Skemer, M., Green, P.J., and Herget, D. (2007). *Highlights From PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context* (NCES 2008–016). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Balzer, W. K., Doherty, M. E., & O'Connor, R. (1989). Effects of cognitive feedback on performance. *Psychological Bulletin, 106,* 410-433.

Bandura, A. (1978). Reflections on self-efficacy. In S. Rachman (Ed.), *Advances in behavior research and therapy* (Vol. 1., pp. 237-269). Oxford: Pergamon.

Bandura, A. (1986). *Social foundation of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: Freeman.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urdan (Eds.), *Self-efficacy beliefs of adolescents* (pp. 307-337). Greenwich, CT: Information Age Publishing.

Bandura, A. (2008). Toward an agentic theory of the self. In H. W. Marsh, R. G. Craven, & D. M. McInerney (Eds.), *Self-processes, learning, and enabling human potential: Dynamic new approaches* (pp. 15-49). Charlotte, NC: Information Age.

Bandura, A, & Wood., R. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision making. *Journal of Personality and Social Psychology, 56,* 407-415.

Bangert-Drowns, R. L., Kulik, J. A., & Kulik, C.-L. C. (1991). Effects of frequent classroom testing. *Journal of Educational Research, 85,* 89-99.

Bangert-Drowns, R. L., Kulik, C.-L. C., Kulik, J. A., & Morgan, M. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research, 61,* 213-238.

Black, P., & Wiliam, D. (1998a). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice, 5*, 7-71.

Black, P., & Wiliam, D. (1998b). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan, 80*, 139-148.

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2003). *Assessment for learning: Putting it into practice.* New York: Open University Press.

Blackwell, L., Trzesniewski, K., & Dweck, C.S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78,* 246-263.

Bloom, B. S. (1968). Learning for mastery. Instruction and curriculum. *Evaluation Comment, (UCLA-CSIEP), 1*, 1-12.

Bloom, B. S. (1969). Some theoretical issues relating to educational evaluation. In R. W. Tyler (Ed.), *Educational evaluation: New roles, new means: The 68th yearbook of the National Society for the Study of Education* (Pt. 2, pp. 26-50).

Bloom, B. S. (1985). *Developing talent in young people.* New York, NY: Ballatine Books.

Bloom, B. S., Madaus, G. F., Hastings, J. T. (1981). *Evaluation to improve learning.* New York: McGraw-Hill.

Bloom, B. S., Hastings, J. T. & Madaus, G. F. (1971). *Handbook of formative and summative evaluation of student learning.* New York: McGraw-Hill.

Boekaerts, M. & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology: An International Review, 54,* 199-231.

Boekaerts, M., Pintrich, P. R., & Zeidner, M. (2000). *Handbook of self-regulation.* San Diego: Academic Press.

Bransford, J. D., Brown, A. L., & Cocking, R. (2000). *How people learn: Brain, mind, experience, and school.* Washington, D.C.: National Academy Press.

Broadfoot, P. M., Daugherty, R., Gardner, J., Gipps, C. V., Harlen, W., James, M., et al. (1999). *Assessment for learning: Beyond the black box.* Cambridge, UK: University of Cambridge School of Education.

Brookhart, S. M. (1994). Teachers' grading: Practice and theory. *Applied Measurement in Education, 7,* 279-301

Brookhart, S. M. (2007). Expanding views about formative classroom assessment: A review of the literature. In J. H. McMillan (Ed.), *Formative classroom assessment: Theory into practice* (pp. 43-62). New York, NY: Teachers College Press.

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: Effects of different feedback conditions on motivational perceptions, interest, and performance. *Journal of Educational Psychology, 79,* 474-482.

Butler, R. (1988). Enhancing and undermining intrinsic motivation: The effects of task-involving and ego-involving evaluation on interest and performance. *British Journal of Educational Psychology, 58,* 1–14.

Butler, R., & Nisan, M. (1986). Effects of no feedback, task-related comments, and grades on intrinsic motivation and performance. *Journal of Educational Psychology, 78,* 210-216.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65,* 245-281.

Campillo, M. (2005). Acquisition and transfer of a writing revision strategy: A self-regulatory analysis. *Dissertation Abstracts.*

Carver, C. S., & Scheier, M. F. (1990). Origins and functions of positive and negative affect: A control-process view. *Psychological Review, 97,* 19-35.

Cleary, T. J., Zimmerman, B. J. (2004). Self-regulation empowerment program: A school-based program to enhance self-regulated and self-motivated cycles of student learning. *Psychology in the Schools, 41*, 537-550.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20,* 37-46.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Erlbaum Associates.

Covington, M. V. (2000). Goal theory, motivation, and school achievement: An integrative review. *Annual Review of Psychology, 51*, 171-200.

Crooks, T.J. (1988). The impact of classroom evaluation practices on students. *Review of Educational Research, 58,* 438-481.

Dewey, J. (1916). *Democracy and Education: An introduction to the philosophy of education.* NY: Free Press.

Dignath, C., Buettner, G., & Langfeldt, H. (In press). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review,* http://dx.doi.org/10.1016/j.edurev.2008.02.003.

Cite effect sizes of feedback effects in their meta-analysis of primary school level self-regulatory interventions.

Dunning, D., Heath, C., & Suls, J. M. (2004). Flawed self-assessment: Implications for health, education, and the workplace. *Psychological Science in the Public Interest, 5*, 69-106.

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development.* Philadelphia: Psychology Press.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95,* 256-272.

Elliott, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54,* 5-12.

Fontana, D., & Fernandes, M. (1994). Improvements in mathematics performance as a consequence of self-assessment in Portuguese primary school pupils. *British Journal of Educational Psychology 64,* 407-417.

Fuchs. L. S. (1995). *Connecting Performance Assessment to Instruction: A Comparison of Behavioral Assessment, Mastery Learning, Curriculum-Based Measurement, and Performance Assessment.* ERIC Digest E530.

Fuchs, L. S., & Fuchs, D. (1986). Effects of systematic formative evaluation: A meta-analysis. *Exceptional Children, 53,* 199-208.

Fuchs, L.S., Fuchs, D., Karns, K., Hamlett, C., Katzaroff, M., & Dutka, S. (1997). Effects of task-focused goals on low-achieving students with and without learning disabilities. *American Educational Research Journal, 34,* 513-543.

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., & Schroeter, K. (2003). Enhancing third-grade students' mathematical problem solving with self-regulated learning strategies. *Journal of Educational Psychology, 95*, 306-315.

Graham, S., & Harris, K. R. (2005). *Writing better: Teaching writing processes and self-regulation to students with learning problems.* Baltimore, MD: Brookes.

Grant, H., & Dweck, C. S. (2003). Clarifying achievement goals and their impact. Journal of *Personality and Social Psychology, 85,* 541-553.

Grigorenko, E. L., & Sternberg, R. J. (1998). Dynamic testing. *Psychological Bulletin, 124,* 75–111.

Guskey, T. R. (2007). Formative classroom assessment and Benjamin S. Bloom: Theory, Research, and Practice. In J. H. McMillan (Ed.), *Formative classroom assessment*. New York, NY: Teachers College Press.

Gutman, L. M. (2006). How student and parent goal orientations and classroom goal structures influence the math achievement of African Americans during the high school transition. *Contemporary Educational Psychology, 31,* 44–63.

Harlen, W. (2006a). The role of assessment in developing motivation for learning. In J. Gardner (Ed.), *Assessment and Learning* (pp. 103-117). Thousand Oaks, CA: Sage Publications.

Harlen, W. (2006b). On the relationship between assessment for formative and summative purposes. In J. Gardner (Ed.), *Assessment and Learning* (pp. 103-117). Thousand Oaks, CA: Sage Publications.

Hattie. J., & Jaeger, R. (1998) Assessment and classroom learning: A deductive approach. *Assessment in Education: Principles, Policy & Practice, 5*, 111-122.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77,* 81-112.

Kitsantas, A. (2002). Test preparation and performance: A self-regulatory analysis. *The Journal of Experimental Psychology, 70*, 101-113.

Kitsantas, A., Reiser, R., & Doster, J. (2004). Developing self-regulated learners: Goal setting, self-evaluation, and organizational signals during acquisition of procedural skills. *The Journal of Experimental Education, 72*, 269-287.

Kitsantas, A., & Zimmerman, B. J. (2006). Enhancing self-regulation of practice: The influence of graphing and self-evaluative standards. *Metacognition and Learning, 1*, 201-212.

Kluger, A. N., & DeNisi, A. (1996). Effects of feedback intervention on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin, 119,* 254-284.

Kulhavy, R. W. (1977). Feedback in written instruction. *Review of Educational Research, 47,* 211-232.

Kulhavy, R. W., & Stock, W. A. (1989). Feedback in written instruction: The place of response certitude. *Educational Psychology Review, 1,* 279-308.

Kulik, C.-L. C., & Kulik, J. A. (1987). Mastery testing and student learning: A meta-analysis. *Journal of Technology Systems, 15,* 325-345.

Kulik, J. A., & Kulik, C. -L. C. (1988). Timing of feedback and verbal learning. Review of *Educational Research, 58,* 79-97.

Ley, K., & Young, D. B. (2001). Instructional principles for self-regulation. *Educational Technology Research and Development, 49*, 93-103.

Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting and task performance.* Englewood Cliffs, NJ: Prentice Hall.

McCaslin, M., & Good, T. (1996). The informal curriculum. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology,* (pp. 622-670). New York: Macmillan.

Messick, S. (1989). Validity. In R. L. Linn (Ed.), *Educational measurement* (3rd ed., pp. 13-103). New York: Macmillan.

Metcalfe, J. (l998). Cognitive optimism: Self-deception or memory-based processing heuristics? *Personality and Social Psychological Review, 2,* 100-110.

Midgley, C. (2002). *Goals, goal structures, and patterns of adaptive learning*. Hillsdale, NJ: Erlbaum.

Midgley, C., Maehr, M. L., Hruda, L. Z., Anderman, E., Anderman, L., Freeman, K. E., Gheen, M., Kaplan, A., Kumar, R., Middleton, M. J., Nelson, J., Roeser, R., & Urdan, T., (2000). *Manual for the Patterns of Adaptive Learning Scales (PALS).* Ann Arbor, MI: University of Michigan.

Narciss, S., & Huth, K. (2004). How to design informative tutoring feedback for multimedia learning. In H. M. Niegemann, D. Leutner, & R. Brunken (Ed.), *Instructional design for multimedia learning* (pp. 181–195). Munster, NY: Waxmann.

Natriello, G. (1987). The impact of evaluation processes on students. *Educational Psychologist, 22,* 155-175.

Newman, R. S. (2007). The motivational role of adaptive help seeking in self-regulated learning. In D. H. Schunk & B. J. Zimmerman (Eds.), *Motivation and Self-Regulated Learning: Theory, Research, and Applications* (pp. 315-337). New York: Lawrence Erlbaum Associates.

Nicholls, J. G. (1984). Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance. *Psychological Review, 91,* 328-346.

Organization for Economic Cooperation and Development (OECD, 2004). *PISA. Learning for tomorrow's world. First results from PISA 2003.* Paris: OECD Publishing.

Pajares, F. (1996). Self-efficacy beliefs in achievement settings. *Review of Educational Research, 66,* 543-578.

Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*, 193-203.

Pajares, F., & Urdan, T. (Eds.) (2006). *Adolescence and education, Vol. 5: Self-efficacy beliefs of adolescents.* Greenwich, CT: Information Age.

Pape, S. J., & Smith, C. (2002). Self-regulating mathematics skills. *Theory Into Practice, 41*, 93-101.

Pintrich, P. R. (2000a). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology, 92,* 544-555.

Pintrich, P. R. (2000b). Goal orientation and self-regulation of learning. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation.* San Diego: Academic Press.

Ramaprasad, A. (1983). On the definition of feedback. *Behavioral Science, 28*, 4-13.

Rosenthal, T. L., & Zimmerman, B. J. (1978). *Social learning and cognition.* New York: Academic Press.

Ross, J. A., Hogaboam-Gray, A., & Rolheiser, C. (2002). Student self-evaluation in grade 5-6 mathematics: Effects on problem solving achievement. *Educational Assessment, 8,* 43-59.

Sadler, R. (1998). Formative assessment: Revisiting the territory. *Assessment in Education, 5,* 77-84.

Schunk, D. H. (1980). Self-efficacy in achievement behavior. *Dissertation Abstracts International, 40,* 3909A.

Schunk, D. H. (1981). Modeling and attributional effects on children's achievement: A self-efficacy analysis. *Journal of Educational Psychology, 73,* 93-105.

Schunk, D. H. (1982). Effects of effort attributional feedback on children's perceived self-efficacy and achievement. *Educational Psychology, 73,* 93-105.

Schunk, D. H. (1983). Ability versus effort attributional feedback: Differential effects on self-efficacy and achievement. *Journal of Educational Psychology, 75,* 848-856.

Schunk, D. H. (1990). Goal-setting and self-efficacy during self-regulated learning. *Educational Psychologist, 25,* 71-86.

Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 26,* 207-231.

Schunk, D. H. (1995). Self-efficacy and education and instruction. In J. E. Maddux (Ed.), *Self-efficacy, adaptation, and adjustment: Theory, research, and application* (pp. 281-303). New York: Plenum Press.

Schunk, D. H. (1996). Goal and self-evaluative influences during children's cognitive skill learning. *American Educational Research Journal, 33,* 359-382.

Schunk, D. H. (1998). Teaching elementary students to self-regulate practice of mathematical skills with modeling. In D. H. Schunk & B. J. Zimmerman (Eds.), *Self-regulated learning: From teaching to self-reflective practice*, (pp. 137-159). New York, NY: Guilford Press.

Schunk, D. H. (1999). Social-self interaction and achievement behavior. *Educational Psychologist, 34,* 219-227.

Schunk, D. H. (2001). Social cognitive theory and self-regulated learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic*

achievement: Theoretical perspectives (2nd ed., pp. 125–151). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Schunk, D. H., & Cox, P. D. (1986). Strategy training and attributional feedback with learning disabled students. *Journal of Educational Psychology, 78,* 201-209.

Schunk, D. H., & Gunn, T. P. (1986). Self-efficacy and skill development: Influence of task strategies and attributions. *Journal of Educational Research, 79,* 238-244.

Schunk, D. H., & Pajares, F. (1992). The development of academic self-efficacy. In A. Wigfield & J. Eccles (Eds.), *Development of achievement motivation* (pp.). San Diego: Academic Press.

Schunk, D. H., & Swartz, C. W. (1993). Goals and progress feedback: Effects on self-efficacy and writing achievement. *Contemporary Educational Psychology, 18,* 337-354.

Schunk, D. H., & Zimmerman, B. J. (1997). Social origins of self-regulatory competence. *Educational Psychologist, 32,* 195-208.

Schunk, D. H., & Zimmerman, B. J. (Eds.). (1998). Self-regulated learning: From teaching to self-reflective practice. New York: Guilford Press.

Schultz, G.F. (1993). Socioeconomic advantage and achievement motivation: Important mediators of academic performance in minority children in urban schools. *Urban Review, 25,* 221-232.

Schutz, P. A. (1993). Additional influences on response certitude and feedback requests. *Contemporary Educational Psychology, 18,* 427-441.

Scriven, M. (1967). The methodology of evaluation. In R. W. Tyler, R. M. Gagné, & M. Scriven (Eds.), *Perspectives of curriculum evaluation*, (pp. 39-83). Chicago, IL: Rand McNally.

Shute, V. J. (2008). Tensions, trends, tools, and technologies: Time for an educational sea change. In C. A. Dwyer (Ed.), *The future of assessment: Shaping teaching and learning* (pp.139-187). New York, NY: Lawrence Erlbaum Associates.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78,* 153-189.

Sternberg, R. J., & Williams, W. (1998) Applying the triarchic theory of human intelligence in the classroom. In R. J. Sternberg, & Williams (Eds.), *Intelligence, instruction and assessment: Theory into practice* (pp. 1-15).

Stiggins, R. J. (2002). Assessment crisis: The absence of assessment for learning. *Phi Delta Kappan, 83*, 758-765.

Stiggins, R. J. (2007). Assessment for learning: An essential foundation of productive instruction. In D. Reeves (Ed.), *Ahead of the curve: The power of assessment to transform teaching and learning*. Bloomington, IN: Solution Tree.

Stobart, G. (2006). The validity of formative assessment. In J. Gardner (Ed.) *Assessment and learning* (pp. 133-146). London: Sage.

Thorndike, E. L. (1913). *Educational psychology* (Vol.1-3). New York: Columbia University Press.

Thorndike, E. L. (1927). The law of effect. *American Journal of Psychology, 39*, 212-222.

Tittle, C. K. (1994). Toward an educational psychology of assessment for teaching and learning: Theories, contexts, and validation arguments. *Educational Psychologist, 29,* 149-162.

Torrance, H. (1993). Formative assessment: Some theoretical problems and empirical questions. *Cambridge Journal of Education, 23*, 333-343.

Urdan, T. C., & Maehr, M. L. (1995). Beyond a two–goal theory of motivation and achievement: A case for social goals. *Review of Educational Research, 65,* 213–243.

Usher, E. L., & Pajares, F. (2005, April). *Inviting confidence in school: Sources and effects of academic and self-regulatory efficacy beliefs.* Paper presented at the meeting of the American Educational Research Association, Montreal.

U. S. Department of Education (2002). *No Child Left Behind Act of 2001a*, Pub. L. No. 107-110, 115 Stat. 1425. Washington, DC.

Wiggins, G. P. (1998). *Educative assessment: Designing assessments to inform and improve student performance.* San Francisco: Josey-Bass.

Wiliam, D. (2007). Keeping learning on track: Classroom assessment and the regulation of learning. In F. K Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. 3, pp. 1053-1098.). Charlotte, NC: Information Age Publishing.

Wiliam, D. (2008). Balancing dilemmas: traditional theories and new applications. In A. Havnes & L. McDowell (Eds.), *Balancing dilemmas in assessment and learning in contemporary education* (Vol. 10, pp. 269-283). London, UK: Routledge.

Winne, P. H. (2001). Self-regulated learning viewed from models of information processing. In B. Zimmerman & D. Schunk (Eds.), *Self-regulated learning and*

academic achievement: Theoretical perspectives (pp. 153-189). Mahwah, NJ: Erlbaum

Winne, P.H., & Jamieson-Noel, D.L. (2002). Exploring students' calibration of self-reports about study tactics and achievement. *Contemporary Educational Psychology, 27,* 551–572.

Wood, R., & Bandura, A. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision making. *Journal of Personality and Social Psychology, 56,* 407-415.

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81,* 329-339.

Zimmerman, B. J. (1995). Self-efficacy and educational development. In A. Bandura (Ed.), *Self-efficacy in changing societies* (pp. 202-231). New York: Cambridge University Press.

Zimmerman, B. J. (2002a). Becoming a self-regulated learner: An overview. *Theory into Practice, 41,* 64-70.

Zimmerman, B. J. (2002b). Achieving self-regulation: The trial and triumph of adolescence. In F. Pajares & T. Urdan (Eds.), *Academic motivation of adolescents, 2,* 1-27.

Zimmerman, B. J. (2004). Sociocultural influence and students' development of academic self-regulation: A social-cognitive perspective. In D. M. McInerney & S. Van Etten, (Eds.), *Big theories revisited* (pp. 139-164). Information Age: Greenwich, CT.

Zimmerman, B. J. (2006). Development and adaptation of expertise: The role of self-regulatory processes and beliefs. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman, (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 705-722). New York: Cambridge University Press.

Zimmerman, B. J. (2008). In search of self-regulated learning: A personal quest. In H. W. Marsh, R. G. Craven, & D. M. McInerney (Eds.), *Self-processes, learning, and enabling human potential: Dynamic new approaches* (pp. 171-191). Charlotte, NC: Information Age.

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal, 45,* 166-183.

Zimmerman, B. J., Bonner, S., & Kovach, R. J. (1996). *Developing self-regulated learners: Beyond achievement to self-efficacy.* Washington, D.C.: American Psychological Association.

Zimmerman, B. J., & Campilo, M. (2003). Motivating self-regulated problem solvers. In J. E. Davidson & R. J. Sternberg (Eds.), *The nature of problem solving* (p. 239). New York: Cambridge University Press.

Zimmerman, B. J., & DiBenedetto, M. K. (2008). Mastery learning and assessment: Implications for students and teachers in an era of high-stakes testing. *Psychology in the School, 45,* 206-216.

Zimmerman, B. J., & Kitsantas, A. (1996). Self-regulated learning of a motoric skill: The role of goal setting and self-monitoring. *Journal of Applied Sport Psychology, 8,* 69-84.

Zimmerman, B. J., & Kitsantas, A. (1997). Developmental phases in self-regulation: Shifting from process goals to outcome goals. *Journal of Educational Psychology, 89,* 29-36.

Zimmerman, B. J., & Kitsantas, A. (1999). Acquiring writing revision skill: Shifting from process to outcome self-regulatory goals. *Journal of Educational Psychology,99,* 241-250.

Zimmerman, B. J., & Kitsantas, A. (2002). Acquiring writing revision and self-regulatory skill through observation and emulation. *Journal of Educational Psychology, 94*, 660-668.

Zimmerman, B. J., & Kitsantas, A. (2005). The hidden dimension of personal competence: Self-regulated learning and practice. In A. J. Elliot & C. S. Dweck (2005), *Handbook of competence and motivation* (pp. 509-526). New York: Guilford Press.

Zimmerman, B. J., & Moylan, A. (2009). Self-regulation: Where metacognition and motivation intersect. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education*. New York: Routledge.

Zimmerman, B. J., Moylan, A., Hudesman, J., White, N., & Flugman, B. (2008, March). *A self-regulatory intervention for at-risk mathematics students in an urban technical college.* Paper presented at the 2008 Annual Meeting of the American Educational Research Association: New York, NY.

Zimmerman, B. J., & Schunk, D. H. (2007). Motivation: An essential dimension of self-regulated learning. In D. H. Schunk & B. J. Zimmerman (Eds.), *Motivation and self-*

regulated learning: Theory, research, and applications (pp. 1-30). New York: Lawrence Erlbaum Associates.