EXAMINING THE EFFECTS OF PROCESS FEEDBACK ON HIGH SCHOOL STUDENTS' SHIFTS IN SELF-REGULATED LEARNING AND MATHEMATICS PERFORMANCE

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Abstract

The current dissertation experimentally examined the differential effects of two types of process feedback (i.e., externally provided process feedback [EXPF] and self-recorded process feedback [SRPF] relative to an outcome feedback only condition across measures of mathematics achievement and self-regulated learning (SRL). Using a sample of 60 suburban high school students (i.e., 9th through 11th grade), the author also investigated shifts in students' SRL processes throughout the mathematical problem-solving (MPS) practice activity. All participants received identical MPS strategy instruction before the practice session and were provided with outcome feedback about their performance on practice mathematics problems; the two experimental groups received the additional manipulation of process feedback (i.e., either EXPF or SRPF). SRL was measured through microanalytic questions that examined students' forethought and performance control phase processes (i.e., self-efficacy, goal setting, strategic planning and strategy use) during an MPS practice session. Math achievement was measured using three MPS problems during a practice session, as well as via the MPS posttest. MPS problems were created in collaboration with an Algebra II teacher at the target high school to ensure appropriate difficulty level and to identify the specific strategies needed to complete these problems. Procedures for providing SRPF and EXPF were established by prior research (Cleary, Zimmerman, & Keating, 2006; Schunk & Swartz, 1993). Analysis of variance was utilized to assess group differences in SRL and mathematics measures among SRPF, EXPF, and control conditions. In contrast to hypotheses, the feedback manipulation did not result in significant group differences in SRL or MPS performance, nor in shifts in students' SRL processes within a given group. The author provided several possible reasons for lack of significant findings, including the strength of the feedback manipulation, the difficulty level of the mathematics problems, and duration of the practice session. Despite the null findings, this study has important implications regarding the key parameters needed for process feedback to exert positive effects during a complex academic task. Recommendations for future research and implications for school psychologists are emphasized.

Acknowledgements

In the word of God, a disciple of Jesus Christ shares the following:

> But he said to me, 'My grace is sufficient for you, for my power is made perfect in weakness.' Therefore I will boast all the more gladly of my weaknesses, so that the power of Christ may rest upon me. For the sake of Christ, then, I am content with weaknesses, insults, hardships, persecutions, and calamities. For when I am weak, then I am strong (2 Corinthians 12:9-10, The English Standard Version).

Above all else, I praise my Savior for carrying me and sustaining me through this dissertation process. When fear, pride, or other obstacles threatened to overwhelm and paralyze me, my God reminded me that my identity belongs to Him as His child (1 John 3:1-2, ESV; Psalm 139:14, ESV). All the glory of completing this project goes to God for it was accomplished through His power, and His might alone.

Second only to Jesus Christ, I am humbled by and thankful for my family. Mom and Dad, I continually tell people that I never would have had the courage to take on this giant if I did not have you backing me up. Dad, you are never afraid. Mom, you trust in God without taking your eyes off Him. In so many ways you both direct me back to God and shower me with His love here on earth. Thank you for being my constant prayer warriors, supporting me through all of the spiritual and earthly battles, and unconditionally believing in me. Kaitlin, I'm so thankful you never leave my side. You always let me follow your footsteps and GSAPP has been no different. Your incredible example and loving guidance always pushes me back to each challenge while shouting from the rooftops that I am able. I am in awe of your strength, ferocity, and genuine desire to be an ambassador for Christ within the field of school psychology and I aspire to do the same. Liam, you ground me in humor, the word of God, and the end goal. I am so thankful for your patience with me throughout this process and your continual insight into the necessity in leaving it all out on the field (or page). Jon, I am thankful God has blessed me with you as an additional family member throughout this time, as you have supported me with your encouraging words and unfailing kindness. This project was completed during a time in my and my family's life of a life-changing struggle, as we wait on God for healing for my sister. This project is a testimony to the power of the Holy Spirit and truth in Jesus' statement, "'With man this is impossible, but with God all things are possible'" (Matthew 19:26, ESV).

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Introduction

Feedback represents an important source of information that describes an individual's performance, knowledge or skills. The ultimate goal of feedback is to decrease the discrepancy between what the learner understands or can do relative to some standard or expectation (Hattie & Timperley, 2007). Hattie and Timperley (2007) define feedback as, "information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding" (p. 81). Research has shown that feedback is a causal determinant of academic achievement. Specifically, it has been identified as one of the top five to ten most positive influences on achievement along with other variables, such as direct instruction, students' prior cognitive ability, prescribing more homework, and smaller class sizes (Hattie, 1999).

Feedback is also considered to be among the most important environmental influences on the development of the self-regulated learning (SRL) process (Black & William, 1998; Butler & Winne, 1995; Fisher & Frey, 2009; Gibbs and Simpson, 2004; Hattie & Timperley, 2007; Kluger & DeNisi, 1996). SRL refers to a process in which human beings exert control over their behaviors, cognitions, or affect, and interact with the environment as they monitor and adjust strategies and actions to meet a goal or standard (Schunk & Zimmerman, 2012). Integral to Zimmerman's (2000) SRL model, learners can generate their own feedback or receive feedback from others. Regardless of the source, feedback is a critical determinant of self-regulated learning because it enables learners to self-evaluate and to identify potential ways to improve future learning. Helping student to become more efficient regulators is important given the large literature base showing that self-regulated learners are "more effective, confident, resourceful, and persistent in learning" (Chung & Yuen, 2011, p. 22; Winne & Hadwin, 1998; Zimmerman & Campillo, 2003).

The feedback literature shows that some types of feedback are more powerful than others (Hattie & Timperley, 2007; Kulhavy & Wager, 1993; Lipnevich & Smith, 2008; Mory, 2003). Due to its impact on achievement and SRL, it is crucial to understand the differentiated effects of feedback type on a person's ability to use the feedback to improve learning. Performance or outcome feedback is the most common type of feedback and describes the level of correctness of responses or overall performance on some task (Butler & Winne, 1995). Outcome feedback about how well a task is being accomplished or performed can positively impact performance. However, when this feedback is the only information provided, it can undercut students' attempts to self-regulate because it directs student focus on results rather than the strategies needed to attain their goals (Hattie & Timperley, 2007). Given that outcome feedback tends to be most beneficial when paired with cues that prompt students to search for strategy information in a task or situation (Harackiewicz, 1979; Harackiewicz, Mabderlink, & Sansone, 1984), it is useful to think of this type of feedback as a necessary but not sufficient condition for helping students to adapt.

Process feedback is another type of feedback. It involves information about one's use of learning processes and strategies (Balzer, Doherty, & O'Connor, 1989). Feedback information about the processes used to complete a task focuses on connecting how one approaches a given activity to the ways in which they might need to adapt this approach on future related tasks (Hattie & Timperley, 2007). Facets of process feedback may prompt improvement in students' strategies for error detection or more effective information search techniques. Due to these components, process feedback can exert a more powerful influence on learners' task strategies than outcome feedback (Hattie & Timperley, 2007). Research shows that process feedback can be particularly powerful for enhancing deeper learning and processing, as well as mastery of tasks (Balzer et al., 1989; Hattie & Timperley, 2007).

Learners can receive any type of feedback from external sources, such as teachers, parents, or computers, or from internal processes, such as self-monitoring and recording. The current study examines external process feedback (EXPF) (i.e., provided by an external source) and self-recorded process feedback (SRPF) (i.e., learners self-generate process feedback). Both SRPF and EXPF inform learners about their skills or task performance by directing attention to essential strategic requirements of a task, or the behaviors and processes that need to be adapted to correct mistakes (Sandars & Cleary, 2011). Both EXPF and SRPF provide information to students about their engagement and approach to a learning activity that may prompt them to engage more systematically in learning through different modalities (Schunk & Rice, 1993). Therefore, both have the potential to promote a more regulated approach to learning. However, the mode of feedback delivery (external vs. self) may have important instructional implications and differential effects. EXPF has been described as the most relevant type of external feedback for effective or enhancing self-regulation processes, though it is rarely given (Sandars & Cleary, 2011). From an SRL perspective, however, a learner does not need to rely on external forms of feedback. They have the capacity to self-generate information about their performance and skills such as through SRPF. The inclusion of self-monitoring as part of the feedback process has important implications for growth in students' internal self-regulatory processes and students' subsequent motivational or academic presentation. It is important that research explore the differential effects of process feedback from diverse sources in order to better understand how educators can provide optimal supports for students during academic tasks.

The primary objective of the current dissertation was to experimentally examine the differential effects of two types of process feedback (EXPF and SRPF) relative to outcome feedback on the mathematics achievement and SRL skills of high school students during a mathematics word problem practice session. Mathematical problem-solving (MPS) was chosen as the context in which to study the relationship between SRL and feedback because it is an academic task that often necessitates the use of SRL skills and complex thinking skills such as critical thinking and problem-solving. Research has also documented a strong connection between SRL and positive MPS outcomes (Kitsantas, 2002; Schunk & Zimmerman, 1998).

Feedback: Types and Importance

Feedback can provide powerful information about performance or understanding that learners can use to adapt their behavior and cognition or to improve knowledge (Fyfe, Rittle-Johnson & DeCaro, 2012; Mory, 2004). As noted previously, outcome feedback provides information on accuracy to help students build surface knowledge of a task (Hattie, 2012). This is the most common type of feedback observed in the classroom. An example of outcome feedback is telling a student when an answer is correct or incorrect such as the correct answer for a math problem (i.e., knowledge of results) (Hattie, 2012; Hattie & Timperley, 2007). Outcome feedback can increase students' awareness of the quality of their achievement and may affect students' confidence about their achievement, which can positively influence motivation and achievement in the long run (Labuhn, Zimmerman, Hasselhorn, 2010; Stone, 2000). Though outcome feedback can help learners identify how well they performed, it does not provide specific information to help them adjust their behavior when they do not perform well. Outcome feedback is also limited because it often does not promote the generalization of students' learning to other tasks and gives minimal external guidance for regulation (Butler & Winne, 1995; Hattie & Timperley, 2007). The narrow scope of outcome feedback fails to guide the learner toward future adaptive behaviors that may be needed when engaging in a complex or unstructured task, wherein the learner may not yet understand how his or her behaviors led to the current performance outcome (Campbell, 1988; Northcraft, Lee, & Lituchy, 1990).

In general, outcome feedback is most effective when used for simple tasks or to convey student misconception, rather than a fundamental lack of knowledge (Balzer et al., 1989; Hattie & Timperely, 2007). For example, Brainerd (1972) demonstrated that providing outcome feedback to children solving novel conservation tasks (i.e., a task kindergarteners typically struggle with) improved children's explanations on subsequent problems. Conversely, Schraw, Potenza, and Nebelsick-Gullet's (1993) experimental study provided students with outcome feedback on reading comprehension and math performance and did not result in significant effects on test achievement. Schraw et al. (1993) attributed this nonsignificant finding to outcome feedback's lack of power to sufficiently affect self-regulation during a more complex task. Because MPS is a complex activity, it is likely that outcome feedback alone may not be enough to initiate self-regulation and, thereby, affect MPS achievement.

In fact, EXPF has been shown to be more powerful than outcome feedback for promoting deeper levels of learning (Hattie, 2012). Research comparing the effects of outcome feedback and EXPF with 10th grade students in mathematics supported the superiority of EXPF. Students who received EXPF showed higher levels of motivation, thought more deeply about mathematics, and engaged in more strategic planning (Ng & Kaur, 2014). EXPF aims to help the student improve the processes used to create the product. Its effectiveness, in part, is the result of providing information about how students perform a task. EXPF refers to when an individual other than the learner, such as a teacher or peer, provides information to the learner with the purpose of reinforcing the importance of learning strategies and directing the learner's focus to using the strategy to improve performance (Schunk & Rice, 1993). In this way an outside source directs students' focus to re-strategizing how they approach a task or develop new strategies for learning (Earley, Northcraft, Lee, & Lituchy, 1990). For example, an EXPF statement might include, "You're asked to compare these ideas. For example, you could try to see how they are similar, how they are different…How do they relate together?" (Hattie, 2012, p. 8). A more succinct example of an EXPF statement is, "You need to complete this task by using the strategies we talked about earlier" (Hattie & Timperley, 2007).

EXPF has been shown to have a positive effect on motivation, satisfaction, and performance, because this type of feedback informs students of their capabilities and progress in learning, which motivates students to continue to perform well (Geister, Konradt, & Hertel, 2006; Schunk & Pajares, 2002). EXPF has also been shown to be effective for enhancing learning or task completion. For example, Schunk and Rice (1993) demonstrated that when children received EXPF that explicitly linked strategy use with improved performance, the students demonstrated higher self-efficacy, higher comprehension skills, and self-reported greater strategy use than students who did not receive feedback other than the outcome feedback that all students received (Schunk & Rice, 1993). Zimmerman and Kitsantas (2002) explored the effect of modeling and EXPF on college students' self-regulatory writing revision skill acquisition. Importantly, the addition of EXPF led to gains in self-efficacy and skill in writing revision. Schunk and Swartz (1993a) reported another study in which authors provided EXPF (labeled progress feedback in their study) in combination with assisted goal-setting to elementary-school children engaged in a paragraph writing task. Schunk and Swartz (1993a) selected EXPF rather than SRPF because of the difficulty inherent in gauging feedback independently within the writing task. Results demonstrated that compared to no-feedback conditions, students receiving EXPF showed higher self-efficacy, writing skill and strategy use, as well as maintenance and generalization (Schunk & Swartz, 1993a).

SRPF delivers process feedback in a different way than EXPF. When teachers promote SRPF, they focus "on helping the student to monitor his or her own learning process" (Hattie, 2012, p. 8). This feedback may come in the form of prompting the student to engage in self-reflection by providing visual prompts or comments such as, "You checked your answer with the resource book [self-help] and found that you got it wrong. Do you have any idea why you got it wrong? What strategy did you use? Can you think of another strategy to try?" (Hattie, 2012, p. 8). Whereas in EXPF an external source tells the student what strategies he or she should return to, SRPF engages the student in the feedback process by cueing the student to engage in error detection, self-assessment, and further strategic processes. This SRPF process can increase students' confidence to continue to engage with the task, while also encouraging the student to seek and accept feedback. Specifically, as a student self-monitors changes in his or her own learning, this SRPF process can have the added benefit of self-reinforcement and enhancing self-efficacy beliefs in addition to providing feedback about the utility of specific learning strategies (Schunk & Zimmerman, 1997).

Self-monitoring refers to "deliberate attention to some aspect of one's behavior, and is often accompanied by recording its frequency or intensity" (Schunk, 1983, p. 89). In the context of mathematics instruction, self-monitoring has been found to positively affect students' achievement and perceptions of self-efficacy. In general academic contexts, self-monitoring has also been found to significantly increase students' time on task, academic accuracy, and writing skill (Carr & Punzo, 1993; Sagotsky, Patterson, & Lepper, 1981; Schunk, 1983; Zimmerman &

Kitsantas, 1999). Although SRPF and EXPF are highly similar in that they return the focus to strategies for the learning task, they differ in the source of the feedback. Whereas EXPF involves feedback provided by an outside source, SRPF involves learners in employing tactics or personal processes to self-generate information that directs their attention to more strategic approaches to learning and task engagement. SRPF can occur by specifically directing students to self-generate their own process feedback such as by saying, "Check to see whether you did this strategy."

An additional benefit to SRPF is that internal feedback has been connected with the development of internal self-regulatory processes. A key tenet of SRPF is that it engages the learner in self-monitoring. Self-monitoring helps a learner become more aware of, and build, connections between outcomes and the suitability or inappropriateness of his or her efforts and responses (Chung & Yuen, 2011). Self-monitoring focuses students on the process of learning and engages students in the self-reflective process, which powerfully supports learners' self-regulated learning and achievement (Kitsantas & Zimmerman, 2006; Stone, 2000). For example, research has shown that self-monitoring often influences students' self-efficacy because students view themselves as more capable of continuing the task in a self-directed manner (Hattie & Timperley, 2007). Recently, some authors assert that higher education should organize instruction with SRPF wherein students assess their own work and generate their own feedback. When students take proactive roles there is a positive impact on performance that occurs as students take ownership of their own learning by generating and using feedback (Boud & Molloy, 2013; Nicol & Macfarlane-Dick, 2006). For example, Zimmerman and Kitsantas (1999) investigated the development of high-school students' self-regulatory writing revision skills through manipulation of goal-setting (i.e., students were provided an outcome-goal, process-goal, shifting-goal) and SRPF. Some students in each condition were told to engage in SRPF by recording the number of strategy steps done correctly during the task or to engage in outcome feedback by recording the number of words in the steps. The control condition did not receive goals or SRPF. Results indicated that students who engaged in SRPF demonstrated increased writing skill and self-efficacy.

Cleary, Zimmerman, and Keating (2006) demonstrated that students who self-monitored their process (engaged in SRPF) began to reflect and evaluate themselves in more strategic ways. Cleary et al. (2006) examined the impact of multiple self-regulatory phases in college students' free throw shooting performance, shooting adaptation, and motivational profiles. Experimental conditions included manipulations of self-regulatory instruction including setting process goals, providing SRPF through students self-recording their performance processes, and making strategic attributions and adaptive inferences. Results indicated that students who set process goals and self-recorded their own feedback demonstrated better shooting accuracy and recovery skill in comparison to students who did not engage in SRPF. Cleary et al. (2006) emphasized the power of this finding because students engaging in SRPF received less practice due to the need to spend time self-recording their techniques; therefore the quality of receiving the SRPF feedback was more important than the quantity of practice. Students receiving the SRPF intervention also evidenced more adaptive reflection-phase SRL processes, such as making more strategic attributions and adaptive inferences during their self-reflection of their performance (Cleary et al., 2006). In this way, the self-monitoring process can also lead to spontaneous changes in other regulatory processes.

Research also shows that when students are provided self-monitoring prompts they demonstrate a more integrated understanding of the concepts (Davis, 2000). Zhang et al. (2004) implemented SRPF by providing students with reflection notes to complete that asked students to reflect on the experiment, as well as a form that asked students to think over the process they had engaged in and the discoveries they had made. Students who received this type of evaluation support in the form of SRPF outperformed non-SRPF students on multiple performance measures (Zhang et al., 2004). In Hattie's (2012) review of evidence assessing the impact of various strategies for student learning, self-recording information (effect size of 0.62) and self-evaluation (effect size of 0.59) are highlighted. Lavery (2008) also listed self-monitoring (as defined as observing and recording one's own performance and outcomes) as one of the learning strategies with the highest impact on learning. The SRPF manipulation in the current dissertation engaged student in self-monitoring and self-recording within the feedback framework in that students were met with self-reflective questions about their learning processes and asked to monitor and record that information.

SRPF can have the added benefit of promoting autonomy by actively engaging a learner in being his or her own agent of feedback. Self-determination theory defines autonomy as "acting with a sense of volition and having the experience of choice" (Gagné & Deci, p. 333, 2005). Researchers have posited that the more fully a behavior is internalized, the more autonomous the subsequent behavior will be (Gagné & Deci, 2005). SRPF is one mode to guide individuals in transforming the external process of feedback into internal regulation. This can lead to a student's greater investment in his or her own regulatory processes. Schunk (1983) alluded to this added benefit in that feedback in the form of self-monitoring can foster a sense of responsibility within students to gain information on their own.

Though research has begun to examine how process feedback affects certain SRL processes, the mechanisms of this relationship have still not been fully explored with regard to the differential impact of SRPF and EXPF (Ahmad, 1988; Fyfe, Rittle-Johnson, & DeCaro, 2012; Luwel, Foustana, Papadatos, & Verschaffel, 2011) and other strategic SRL processes (Hudesman, Zimmerman, & Flugman, 2010). Though studies have suggested additive effects of process and outcome feedback on task performance or SRL, current literature has not fully explored how to enhance feedback to support self-regulation (Northcraft, Lee, & Lituchy, 1990; Nicol & Macfarlane-Dick, 2006). Therefore, more information is needed to understand which of these types of process feedback produces the most adaptive shifts in SRL processes as well as academic performance. This study sought to measure the differential impact of SRPF and EXPF on shifts in SRL processes and performance to address these gaps in the literature (Cleary, Dong, & Artino, 2015; Hattie & Timperley, 2007).

Self-Regulation Defined

Self-regulation refers to a self-directive process in which learners proactively engage in learning and transform their knowledge into skills used for academic tasks (Zimmerman & Schunk, 2001). For example, in the school context, self-regulation is apparent when students are able to set their own goals, plan appropriate strategies to achieve these goals, self-monitor, evaluate and adapt their learning behaviors, and control their use of available strategies and resources. Multiple theoretical perspectives exist regarding the nature of self-regulation including operant, phenomenological, information-processing, social-cognitive, volitional, Vygotskian, and cognitive constructivist approaches (Zimmerman & Schunk, 2001). This study will focus on the social cognitive theory (SCT) of self-regulation as it accounts for personal, behavioral, and environmental influences on learning (Zimmerman & Schunk, 2001).

Expanding upon Bandura’s premise that humans have the ability to exert active control and influence over behaviors through regulatory subprocesses such as self-observation and self-judgments, Zimmerman (2000) defined self-regulation as, “self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (p. 14). SRL describes the process through which human beings exert control over their behaviors, cognitions, affect, and environment. A key aspect to this model is that students will continually self-generate feedback from their performance and will use this information along with external feedback provided by others to adjust their strategic actions in order to meet some academic goal or standard (Schunk & Zimmerman, 1998). SCT asserts that personal self-regulation emphasizes the process of self-monitoring (akin to SRPF), is used "to adjust cognitive and affective states so that an individual can perform with high efficiency" (Chung & Yuen, 2011, p. 22). Behavioral self-regulation is therefore made complete through SRPF processes of self-observation that enable a learner to make strategic adjustments in his or her own responses (e.g., adjust goal-setting, strategic planning, or strategy use actions) as necessary for achieving higher performance.

Research has documented a strong connection between SRL and a variety of positive academic outcomes, such as reading comprehension, writing, science learning, study time, mathematical competency development, and MPS (Callan, 2014; DiBenedetto & Zimmerman, 2010; Schunk, 1983; Schunk & Swartz, 1993). The development of SRL can be facilitated by factors operating in the learning environment such as through outside interventions of feedback (e.g., EXPF) or actively encouraging learners in self-monitoring (e.g., SRPF).

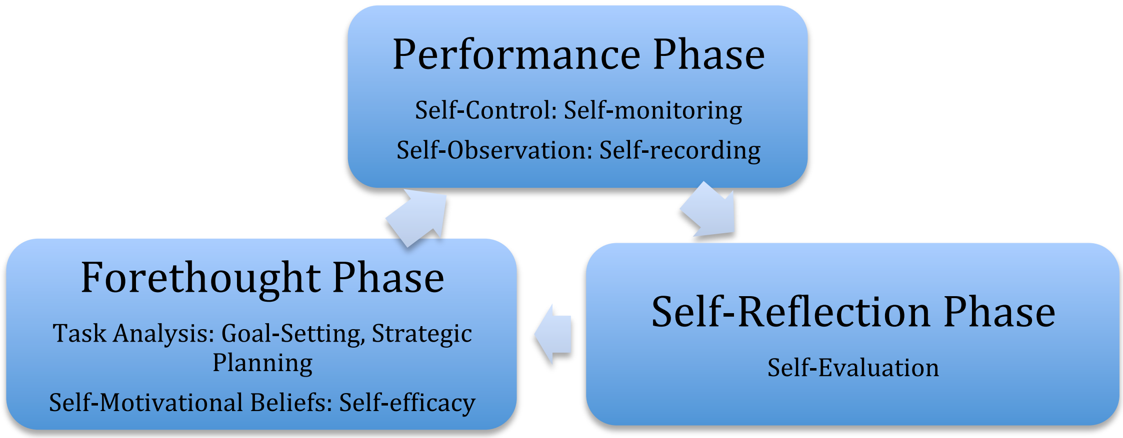

Figure *1*. Processes within Cyclical Model of Self-Regulated Learning
Adapted from "Becoming a Self-regulated Learner: An Overview," by B.J. Zimmerman. 2002. *Theory Into Practice, 41*, p. 67, and informed by "Attaining self-regulation: a social cognitive perspective," by B.J. Zimmerman. 2000. Handbook of Self-Regulation.

Zimmerman (2000) provides a conceptual model of SRL that depicts self-regulatory processes occurring in a cyclical three-phase process in which individuals use a variety of sub-processes to manipulate and manage their cognitions, motivation, and behavior while engaged with a learning task. The three interdependent phases of SRL include the subprocesses of analysis in this study within the forethought, performance, and self-reflection phases (see Figure *1*). The forethought phase processes occur before engaging in a task in order to optimize performance or learning (e.g., setting goals, planning strategies for the task, or monitoring one's self-efficacy for the task). The performance phase processes occur during performance or learning includes the use of strategies to learn and direct behavior as well the use of self-monitoring. The information that students gather during the performance phase is used to stimulate self-reflection. The self-reflection phase processes include self-evaluation, attributions and adaptive inferences. The cycle is complete when self-reflection processes influence subsequent forethought phase processes during a future learning activity (Zimmerman, 2000). A key purpose of feedback (e.g., SRPF, EXPF, outcome) is to enhance self-reflection, due to the interdependent effects on other processes within Zimmerman's (2000) cyclical model (Labuhn, et al., 2010).

Although Zimmerman (1995) discussed the importance of examining a learner's ability to shift regulatory strategies and tactics during an academic task, very few studies have analyzed the relationship between SRL and feedback, or shifts that may occur in SRL processes following different types of feedback (Cleary et al., 2015; Carver & Scheier, 2000; DiBenedetto & Zimmerman, 2010; Zimmerman & Kitsantas, 1999). Examining changes in SRL is important because in real life settings learners will often struggle and will need to demonstrate the ability to adapt their strategies or approach when making repeated attempts on learning tasks. This study aimed to address this literature gap by studying the subsequent shifts in SRL processes that occur in response to EXPF and SRPF throughout students' practice of mathematics problems.

Linking SRL and Feedback to MPS

This study will use mathematics as the target domain of interest. Mathematics was selected for a variety of reasons. Solving a single mathematics problem has been described as a type of regulatory event. That is, as students complete a single math word problem, students will engage in Zimmerman's (2000) cyclical model of cognitive, motivational, and behavioral processes occurring before, during, and after the task. Math word problems have a discrete start and end that enables feedback to be clearly administered. Although research has demonstrated a strong connection between SRL and mathematics outcomes (De Corte, Mason, Depaepe, & Verschaffel, 2011; De Corte, Verschaffel, & Op't Eynde, 2000; Kitsantas, 2002; Pape, & Smith, 2002; Schunk & Zimmerman, 1998), there is a paucity of information examining effective feedback for students' MPS learning.

The academic domain of mathematics is complex because it encompasses several important components, such as a foundational knowledge of math facts, mathematical terminology, concepts, mathematical operations, and computation skills. MPS requires students to synthesize mathematical knowledge and computational skills and effectively execute general academic skills such as reading, writing, and the development of critical thinking skills (Baroody, 2003; Rutherford-Becker & Vanderwood, 2009). Problem-solving is an extremely important skill for students to learn as it is intimately linked with general mathematical achievement. Some authors have gone so far as to state that a primary goal of mathematics teaching and learning is to cultivate problem-solving ability (Bryant, Bryant, & Hammill, 2000; Geary, 2003; National Council of Teachers of Mathematics, 1980; National Council of Teachers of Mathematics, 1989; Wilson, Fernandez, & Hadaway, 1993).

One of the causes of students' mathematical errors is the students' misuse of self-regulatory strategies (such as failed cognitive control or incorrect strategy utilization; Radatz, 1979). By including feedback, this study attempted to understand how EXPF and SRPF impact students' use of SRL processes during an MPS task as well as their SRL and performance.

Purposes and Overall Objectives

The primary objective of this research project was to examine how two types of process feedback (i.e., SRPF and EXPF) affect students' engagement in SRL processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) and students' MPS performance (Callan, 2014; Cleary & Zimmerman, 2004) relative to a condition receiving only outcome feedback. This study also examined the impact of EXPF and SRPF on shifts in students' SRL skills during a mathematics practice session (Cleary et al., 2015).

There are several specific research questions addressed in this study (see Appendix E for a summary of research questions and analyses):

1. **Are there statistically significant differences among feedback groups (i.e., SRPF, EXPF, and control) in terms of self-regulated learning processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use)?**

It was anticipated that students receiving SRPF would demonstrate significantly more adaptive SRL processes than the students receiving EXPF or simple outcome feedback. SRPF was predicted to engender the highest engagement in SRL processes because SRPF guides the student in SRL processes of self-monitoring and self-recording their own process feedback. As discussed previously, when students become more engaged in tracking their own use of strategies, it can influence their use of strategies and achievement on that activity (Hattie, 2012; Lloyd & Trangmar, 2012). SRPF also has the additional benefits in that the inherent self-monitoring process within this feedback can enact spontaneous changes in other regulatory processes or increase a learner's investment in their own regulatory processes (Cleary et al., 2006). Finally, SRPF's potential to promote autonomy by actively engaging a learner as his or her own agent of feedback can have positive implications for a student's sense of ownership of their learning process and ability to inform their own learning (Schunk, 1983). Therefore, it was expected that SRPF would more effectively increase subsequent SRL processes (Hattie, 2012).

It was also hypothesized that students receiving SRPF or EXPF would exhibit superior SRL processes relative to students in the control condition. Firstly, students receiving either type of process feedback were predicted to engage in enhanced SRL processes due to prior research indicating that the emphasis process feedback places on strategies more positively impacts SRL processes than outcome feedback alone (Ng & Kaur, 2014). Feedback about process has been described as not only more effective than outcome feedback, and enhancing deeper learning (Balzer et al., 1989; Hattie & Timperley, 2007, Labuhn et al., 2010) but as the most effective general type of feedback for promoting improvement in student learning (Lipnevich & Smith, 2008).

2. **Are there statistically significant differences among feedback groups (i.e., SRPF, EXPF, and control) in terms of mathematics performance (i.e., as measured by MPS practice Problems and posttest Problems)?**

It was anticipated that students in the SRPF group would demonstrate significantly higher MPS performance on practice problems and at posttest than students in the EXPF and outcome feedback groups. It was hypothesized that students in the SRPF condition would produce higher MPS performance because of its effects on students' subsequent SRL processes. As students engage in more effective SRL during MPS, it is likely that they would perform at a higher level, given the predictive relationships between achievement and SRL (Zimmerman & Martinez-Pons, 1986). It was also expected that students receiving SRPF or EXPF would outperform control students due to prior research indicating higher achievement related to process feedback relative to outcome feedback (Labuhn et al., 2010; Ng & Kaur, 2014; Schraw et al., 1993).

3. **Are there statistically significant shifts in self-regulatory processes within each of the feedback groups (i.e., SRPF, EXPF, and control)?**

This was an exploratory research question given the lack of prior research examining the differential effect of various types of feedback on SRL shifts during an academic task (Cleary et al., 2015). It was anticipated that students in the SRPF and EXPF conditions would demonstrate significantly more adaptive shifts in SRL processes than students in the control condition because the nature of process feedback was expected to stimulate a more effective engagement in future SRL processes within this discrete task in alignment with the interdependent cycle of SRL (Zimmerman, 2000).

It should be noted that that a novel assessment methodology was used in this study to assess students SRL processes; SRL microanalysis. SRL microanalysis is an evidence-based, highly contextualized measurement approach that assesses students SRL processes as they engage in specific learning activities (Cleary, Callan, & Zimmerman, 2012). It provides a sensitive method for measuring SRL processes outlined in Zimmerman's (2000) cyclical model, such as goal-setting, planning, and attributions.

It is also of interest to note that SRL microanalysis was used to measure the shifts in self-regulatory processes in response to EXPF and SRPF during the MPS practice sessions. Prior research has used SRL microanalysis to measure the SRL processes studied in this dissertation. In addition, the specific and structured temporal questioning used in SRL microanalysis (Cleary et al., 2012; Cleary, 2011; DiBenedetto & Zimmerman, 2010) provides a way to systematically study how students use, or fail to use, self-regulatory behaviors and cognitive control during MPS (Butler & Winne, 1995; Schoenfeld, 1992; Wilson, Fernandez, & Hadaway, 1993) in conjunction with feedback delivery. SRL microanalytic measures have also been shown to display acceptable reliability (Cleary, Callan, & Zimmerman, 2012; Cleary, Callan, Peterson, & Adams, 2011; Cleary et al., 2006; Cleary & Zimmerman, 2001).

By enabling data to be collected during the real-time administration of the activity and surrounding feedback, SRL microanalysis presents a way to study how a student uses feedback information in real-time, as advocated for in previous literature (Butler & Winne, 1995; Cleary, 2011; Hattie & Timperley, 2007). SRL microanalysis will also allow the assessment of students' SRL processes during an MPS task that is very similar to the type of task they would encounter in a regular classroom. Such an approach would help to ensure that the results of the assessment are more generalizable to how students naturally conduct themselves (i.e., how specific regulatory behaviors would naturally occur in a mathematics context).

Methods

Sample

Target school. The participating public high school is located in the northeast region of the United States. Based on 2012 -2013 demographic data provided by the New Jersey Department of Education (NJDOE) about the target high school, student enrollment included 1,445 students comprised of 719 (50%) male students and 727 (50%) female students) across 9th to 12th grade (National Center for Education Statistics, 2015; Institute of Education Sciences, 2015). The ethnic/racial breakdown of the student population was as follows: 63.9% White, 18.7% Asian, 9.3% Hispanic, 5.9% African American, 0.1% American Indian, and includes 2.1% students identifying as two or more races. Ten percent of the student population was identified as economically disadvantaged as measured by free and reduced lunch status. Further, 11.0% of the student population was identified with a disability, with 2.0% of the population being of Limited English Proficient status. Based on the NJDOE's assessment of student dropout rates during the four years of high school, the target school has lower dropout rates than approximately two thirds of schools with similar demographic characteristics.

The target school is a relatively high-achieving school when compared to other NJ schools. In comparison to schools across the state, this school has a higher graduation rate than 50% of other NJ schools as it surpasses statewide targets for graduation rates (i.e., 75% of students to graduate within four years) in that 93% of students school-wide graduate within four years. Finally, the target school's college and career readiness is higher than 86% of schools statewide and 92% of schools educating students with similar demographics.

Students. Approximately 192 high school students enrolled at the target school were invited to participate in this study. The initial sample pool included 60 high school students that met eligibility requirements for this study. Of this sample, there were 36 (60%) males and 24 (40%) females. This was comprised of three ninth-grade students, 51 tenth-grade students, and six eleventh-grade students. Table 1 summarizes the categorical variables of interest included in this study, with sample sizes and percentages of response reported for each category. With regard to respondent ethnicity, 70% of the sample was white (non-Hispanic), 6% Asian/Pacific Islander, 6% Hispanic or Latino, 4% Black/African American, and 2% classified as Multiracial.

Table 1

Demographic Characteristics of Student Sample

Measure	*n*	%
Ethnicity		
White	42	70
Black or African American	4	7
Asian/Pacific Islander	6	10
Hispanic or Latino	6	10
Multiracial	2	3
Gender		
Male	36	60
Female	24	40
Grade Level		
9th	3	5
10th	51	85
11th	6	10

Inclusionary criteria for participation included enrollment in one of four sections of the Algebra II course at the target high school. The author elected to select students from this course because of the relatively large number of students taking this course and given that SRL is often conceptualized as a context-specific construct (Cleary & Chen, 2009). Finally, as some of the measures (e.g., SRL microanalysis) required students to verbally express answers, non-fluent English speakers, such as English Language Learners or students who are diagnosed with a cognitive disability, were not recruited for this study. Special education and general education students were included.

Power analysis. Prior to data collection, a power analysis was conducted in order to determine an appropriate sample size. Based on Cohen's (1992) methods for determining sample size with a power analysis, analyses showed that a sample size of 21 students per condition would be needed to detect a large effect with a specified power level of .80 and with an alpha level set at .05. Based on this analysis, a sample of 63 students (21 students per group) was targeted.

Recruitment procedures. In July of 2014, the primary researcher approached the administration of the intended school district and the target high school with a proposal describing the scope and nature of the present study. In November of 2014 and December of 2014, the primary researcher presented the proposed study and general materials to district administrators, staff members, and board members and received approval.

In March of 2015 the Graduate School of Applied and Professional Psychology (GSAPP) and the Rutgers University Arts and Sciences Institutional Review Board (IRB) issued approval for the current study (see Appendix C). Accordingly, the Algebra II teachers at the target high school were informed of the upcoming voluntary study. The primary researcher completed a thorough record review to compile a list of students who would meet eligibility requirements. The record review provided information on students' grades in Algebra II (i.e., midterm and Fall 2014 grades) as well as students' Algebra II teacher. Students' age, gender, ethnicity, grade level, special education classification, and socio-economic status were also obtained through review of school demographic information collected. Socio-economic status was determined by qualification for free and reduced lunch.

The parents of eligible students were contacted via a mailed letter, as well as an emailed notice when possible, with information regarding the study, an invitation letter from the

Principal, and a request for parental consent to include the child in the study (see Appendix D). All documents sent home to parents were approved by the school administration. Experimental administration took place between April 2015 and June 2015.

Initially 132 students were invited to participate in the study with two waves of invitations occurring on March 28, 2015 and April 27, 2015. The second wave of recruitment letters were sent home through email, mailing, and were also given to Algebra II teachers to hand to their students. This pool of students was invited in accordance with the initial set of inclusionary criteria that included the following student characteristics: (a) enrollment in Algebra II, and (b) poor mathematics achievement in Algebra II. The prior mathematic levels of the participating students was analyzed through prior Algebra II Midterm grades and Algebra II course grades from the first half of the year. A student was characterized as low achieving in mathematics if the student: (1) earned a grade of B+ or lower (89% or lower) on the Midterm for Algebra II, and (2) obtained a Fall 2014 semester course grade of B+ or lower (89% or lower) in Algebra II. All students in the Algebra II courses sat for a standard Midterm exam developed by school staff, and the course grade for the Fall 2014 semester of Algebra II consisted of the average of students' course grades over the first two marking periods of the year-long Algebra II course. Special education and general education students were included.

Parental consent and student assent was received by 25 students by April 2015. Due to the insufficient response rate received from the first group of students invited, it was necessary to seek IRB approval, and school district approval, to invite additional students by removing the inclusionary criteria of earning a B+ or lower (89% or lower) on the midterm and the Algebra II Fall 2014 semester grade. The proposal was revised to include all students enrolled in Algebra II at the target high school, including both low-performing students and students who were performing above grade expectations based on Algebra II course and Midterm grades (i.e., a grade of B- or higher). Enrollment in the Algebra II courses at the target high school ensured that all students were still exposed to equivalent material and able to participate in the study session. This also provided the opportunity to analyze the effects of feedback with a more diverse range of students within the Algebra II course criterion.

A teacher-determined incentive, such as extra credit or a homework pass, was also offered to students. This incentive was discussed between the researcher, her dissertation committee, and the teachers at the target school in order to offer each invited student a small incentive upon his or her participation. Four Algebra II teachers were involved from the target high school, and each Algebra II teacher was provided discretion over the type of incentive that participating students would receive. All incentives were added to students' fourth marking period grade for Algebra II. IRB approval and district approval was granted in May 2015 to initiate these changes regarding the Algebra II grades criterion and incentive addition in recruitment. Parents and students who already consented, as well as newly invited students and parents, were informed of the offer of the teacher-determined incentive through the new recruitment notices (see Appendix D). Algebra II classroom teachers provided details to students and parents on the type of incentive students in their Algebra II section would receive. The new recruitment email and mailing notices explained that participating students would now receive an incentive determined by their Algebra II teacher, and the new notices also indicated that participation was now offered to all students enrolled in Algebra II at the target high school. The new notices were sent to students and parents that already consented as well as newly invited students and parents through email and mailing home; teachers handed these out to students during Algebra II class. Algebra II teachers made a general announcement about the study and consent documents during their classes. Teacher incentive was to be provided solely based on study participation, and teachers would not receive any information regarding students' performance in the study session.

By extending the invitation to all Algebra II students, as well as including a teacher-based-incentive, the researcher received 61 consents. One student refused to participate, resulting in a sample of 60 students. All participating students engaged in the single phase of the study, which included one 45-minute session with the primary researcher, completed during the school day.

Measures

Measures of SRL.

SRL microanalytic measurement. SRL microanalytic questions were used to examine students' forethought and performance control phase processes during a mathematics problem-solving (MPS) practice session. Given that most SRL microanalytic questions use an open-ended format, responses needed to be coded into specific categories. This study adhered to the detailed and structured coding scheme developed in prior research to transform students' qualitative responses in these three areas (i.e., goal-setting, strategic planning, and strategy use) into metric values (Cleary, Callan, & Zimmerman, 2012; Callan, 2014). Callan (2014) provides structured procedures for how to (1) code questions (i.e., categorize and code free response questions) and (2) score questions (i.e., transform codes into a metric scale). This process of coding and scoring open-ended SRL microanalytic questions is necessary to conduct appropriate statistical procedures to address the research questions. All of the target microanalytic measures consisted of an individual question that targeted a particular aspect of the SRL process as students engaged in the MPS task: self-efficacy, goal-setting, strategic planning, and strategy use.

Microanalytic self-efficacy. Students' task-specific self-efficacy to solve mathematics word problems was measured with a single-item question used in previous research (Bandura, 2006; Cleary et al., 2015). The self-efficacy question was administered at three separate times during the mathematics practice session: (1) before students begin the first math problem but after students have received strategy instruction, (2) after receiving one of the three types of feedback but before beginning the second math problem, and (3) after students have received feedback about the second problem and before the third problem attempt. Across all assessments, students were asked, "On a scale of 10 to 100 with 10 being not confident, 40 being somewhat confident, 70 being pretty confident, and 100 being very confident how confident are you that you can correctly solve this math problem?" (see Appendix E for self-efficacy cue card and question). Responses were scored on a Likert Scale, which ranged from 10 (not confident) to 100 (very confident) divided into 10-point increments (e.g., 10, 20, 30 etc.; Cleary et al., 2015; DiBenedetto & Zimmerman, 2010). This measure resulted in three individual self-efficacy ratings. The gathering of three self-efficacy estimates was used to assess shifts in self-efficacy scores across multiple iterations of the MPS practice session. Prior researchers demonstrated inter-item reliability of .89 according to Cronbach's alpha test for a similar self-efficacy question (Zimmerman & Kitsantas, 1996).

Microanaalytic goal setting. Goal-setting was measured with a single microanalytic question adapted from prior research (Cleary & Zimmerman, 2001; DiBenedetto & Zimmerman, 2010). The primary researcher read the goal-setting question immediately after the student previewed the mathematics word problems: "Do you have a goal in mind as you prepare to practice these math problems? If so, what is it?" After allowing the student to preview the math word problems, the examiner read the goal-setting question and recorded responses verbatim (Callan, 2014). Prior research has demonstrated microanalytic goal-setting questions to have high levels of inter-rater reliability (kappa = .95; Cleary & Zimmerman, 2001) and to reliably differentiate achievement groups (i.e., learners demonstrating the highest level of performance tend to set more specific goals).

The coding scheme represented a slight variation of a coding scheme used in prior research (Callan, 2014; Callan & Cleary, in press). The coding categories included process-specific, process-general, outcome-goal, other, non-task, and no goal. Because the MPS task did not allow for setting specific outcome goals, Callan's (2014) outcome-specific and outcome-general categories were collapsed into a more general outcome category. Statements that focused on how to specifically use strategies to execute procedures to solve the math problem were coded as process-specific, such as, "I will read the problem", whereas general process responses such as, "I want to do it the right way", were categorized as process-general. Similarly, goals that focused on specific or general outcomes, such as, "I want to get it all right" or "I want to do my best", were labeled as outcome goals. Scoring followed a standardized process from prior research (Callan, 2014; Cleary et al, 2011; see Appendix F). Binary coding was used to note the absence or presence of one of these coding areas. Therefore students received one point if any of the following types of goals were present for each category: process-specific, process-general, outcome, non-task, and no goal. The sum of points awarded for process-specific, process-general, and outcome goals created the total for each goal-setting question. Answers that were coded as "non-task" or "no goal" were not included in the total value for the goal-setting question. One rater coded all goal-setting questions. Two raters independently coded the responses for a sample of 10% of all goal-setting data across the three conditions, and including all three administrations, and yielded a percent agreement of 95%. Similar to the self-efficacy measure, the goal setting measure was administered three times during the MPS activity.

Microanalytic strategic planning. Strategic planning was also measured with a single microanalytic question. The strategic planning question was presented immediately after the student previewed the mathematics word problems: “Do you have any plans for how to successfully complete these math problems?”

Callan’s (2014) coding scheme was utilized which included the following categories: MPS strategy, other, non-task, and don’t know/no plan (see Appendix F). Statements were coded as an “MPS strategy” if they fit one or more of the following 15 categories (e.g., read and re-read, highlight, underline or list, search, identify the problem, paraphrase, re-state, or create an analogous problem, visualization, elaboration, hypothesize/estimate/predict the answer, equation development intention, computation intention, procedures selection, check/monitor understanding, self-questioning, direct references to checking understanding, check performance, and compare solution/estimate).

One point was awarded for each category; thus it was possible for a student’s entire response to receive multiple points. Examples of strategic statements that would earn a point include statements describing reading or re-reading the math problem (i.e., read and re-read), statements wherein students connect the current task demands to prior learning experience (i.e., elaboration), and statements that explicitly reference the need to develop an equation to solve the problem (i.e., equation development intention). Statements that refer to a specific behavior or strategy such as self-control, but were not found in another coding category, were coded as "other", and statements that were unrelated to the task or showed the participant did not know how to approach the problem were coded under "non-task plans" or "don't know/no plan".

Similar to the scoring process for goal-setting questions, students received one point if any of the "MPS strategy" coding categories were present, as well as if responses were coded as other, non-task and no goal/don't know. The points awarded for "MPS strategy" categories were summed to create the total for each strategic planning question. Therefore, scores for the strategic planning questions involved summing the total number of pre-established mathematics strategies (Callan, 2014; DiBenedetto & Zimmerman, 2010). Answers that were coded as "other", "non-task" or "no goal" were not included in the total value for the strategic planning question score. The latter categories did not contribute to strategic planning question scores because they indicate the absence or presence of less adaptive responses. These latter categories were not recorded if at least one other adaptive response was provided. One rater coded all strategic planning questions. Two raters independently coded the responses for a sample of 10% of all strategic planning data across the three conditions, and including all three administrations, and yielded a percent agreement of 97%. Prior research showed that strategic planning microanalytic measure has exhibited high inter-rater reliability and ability to differentiate between experts, non-experts, and novices (kappa=.91) in previous research (Cleary & Zimmerman, 2001; DiBenedetto & Zimmerman, 2010).

Microanalytic strategy use. Strategy use was measured with a single microanalytic question used in prior research (Callan, 2014). The primary researcher read the strategy use question immediately after the participant completed each word problem, and after feedback was provided. The researcher prompted, "Tell me all of the things that you did to solve the problem" as a structured way to assess the quality and number of strategies utilized by the student to complete the word problem. Depending upon the response provided, and whether it fit the coding system, the examiner also prompted, “Is there anything else that you did?” for a maximum of two prompts. The coding and scoring guidelines for this measure were identical to those used for the strategic planning question. Thus, four categories were used: MPS strategy, other, non-task, and don’t know/no plan. One rater coded all questions and two raters independently coded the responses for a sample of 10% of all strategy use data across the three conditions, and including all three administrations. The raters exhibited a percent agreement of 84%. Further, Zimmerman and Kitsantas (2002) have used a similar question to differentiate expertise levels and to predict future performance.

Mathematics achievement

Math achievement was measured by two distinct indices: (a) performance on three MPS problems administered during the study procedures (MPS practice session), and (b) a posttest consisting of two MPS problems following the MPS practice session. The mathematics problems in the MPS practice session and posttest assessment were similar with regard to difficulty levels and types of problem (i.e., all problems involved the same Algebra II content of the application of factoring and area).

Problems were created through consultation with two content experts: (1) Dr. Gregory Callan who has performed empirical research targeting student SRL processes during MPS task completion, and (2) Clare Krulewicz, who was a special education and general education certified mathematics teacher at the target high school. Consultation with Dr. Callan involved discussing the selection of problems, piloting techniques and re-wording of problems, as well as the use of the coding scheme referred to in the Measures section for SRL questions. The problems were created and reviewed with Ms. Krulewicz at the target school to ensure matching of curriculum and to ensure that the participating students were previously exposed to the necessary formulas and instruction through the target high school's Algebra II curriculum. Collaboration with the high school teacher at the target high school ensured that all word problems were of equivalent difficulty level and appropriate difficulty to challenge the participating students (Charles, 2012). Problems were selected to target the same types of MPS skills, which were tied to the strategy instruction all participants received.

In order to target students' MPS skills, mathematics problems were created to assess mathematical application and problem solving as defined by the National Center for Education Statistics (NCES) (IES, 2015). NCES indicates that mathematical application and problem solving involve the use of mathematical knowledge, skill, and understanding to solve routine and non-routine problems by using processes such as "recalling and recording knowledge, selecting and carrying out algorithms, making and testing conjectures, and evaluating arguments and results" (National Assessment of Educational Progress (NAEP) Sample Questions, 2007-2008, p. 8). MPS problems created for this study required students to apply their mathematical knowledge by engaging in these problem-formulation processes.

MPS practice problems. Students completed three MPS problems as part of the study procedures and activities. A copy of the MPS practice problems included in this measure can be found in Appendix E. Students' performance on these word problems was scored according to a rubric created in collaboration between the primary researcher and high school math teacher; this rubric was consistent with scoring procedures used in previous research (Callan, 2014). Callan's (2014) coding system was adapted to measure students' task performance across the three word problems in this study. Students could earn up to three points for completing steps of the problems without errors (i.e., identify the correct equation, solve the equation and plug in values correctly to gain answers of width and length). These steps corresponded to a strategy cue card (see Appendix E) used in the strategy instruction and the scoring system based on research-based MPS strategies (see Appendix G).

The scoring system used in the current study was a slight variation from prior research (Callan, 2014). In order to focus on the purpose of the study to analyze strategic engagement, students only received credit for strategies, as opposed to the original scoring system where students could earn points for evidence of an attempt to solve the problem that would have assessed student effort rather than strategy. Similar to Callan (2014), if a student selected the correct operations but had an incorrect solution due to minor calculation errors, a student could receive half-credit. This was determined because selecting the right procedures, even if the math calculations were incorrect, is more adaptive than selecting incorrect procedures. One rater coded all problems and two raters independently coded the responses for a sample of 10% of all MPS problem data across the three conditions, and including all three administrations. The interrater agreement was 99% for the coding of MPS problems between two raters.

Posttest mathematics problems. Following the completion of the strategy instruction and the MPS practice session, the author administered the posttest measure of two mathematics word problems. These word problems were of the same type and difficulty level of the MPS practice session problems. Procedures for the selection and creation of problems followed the collaborative work done for the MPS practice session problems between the primary researcher and high school mathematics teacher to ensure matching of the Algebra II curriculum and difficulty level (see Appendix E for posttest problems). Performance on the posttest MPS problems was calculated using the same scoring procedures and rubric utilized for the practice session problems (Callan, 2014; Appendix G). This outcome measure served as an indicator of students' MPS skill following strategy instruction and the MPS practice session. One rater coded all problems and two raters independently coded the responses for a sample of 10% of all MPS posttest data across the three conditions, and including all three administrations. The current study demonstrated interrater reliability with a percent agreement of 99% for the coding of MPS posttest problems between two raters.

Prior mathematics achievement. Two indicators of baseline mathematics achievement were gathered: students' Algebra II Midterm grade and Algebra II Fall 2014 course grade. The target high school uses a numerical rating system based on a 100-point scale, in which students receive letter grades (A, B, C, D, and F) and numbers are assigned to these letter grades. The high school does not provide grades of A+ rather grades are provided with these ranges: A (92 – 100), A- (90 – 92), B+ (87 – 89), B (82 – 89), B- (80 – 82), C+ (77 – 79), C (72 – 79), C- (70 – 72), etc. Students enrolled in the Algebra II classes received the same midterm assessment created by the school's Algebra II teachers; therefore, the grade on this measure was used as the primary indicator of students' performance in Algebra II. Grades in Algebra II were assigned by the classroom teacher and were formed by the averaging of class participation, homework, and performance on tests and quizzes. Students received grades at the end of each quarter and grades were then averaged into a year-end final grade. This data was used to systematically assign students across conditions to equate experimental conditions on the background variable of mathematics achievement. This enabled conditions to have equated amounts of students with both high and low achievement in his or her Algebra II class as evidenced by performance on the midterm assessment and Algebra II Fall 2014 grade.

Task Materials

In this study, all students were taken through an MPS activity that involved three math problems. As shown in Appendix D students were issued an informed assent form first. Each session began with the introduction of a strategy instruction using the strategy cue card to provide a visual aide in teaching the five steps of this MPS strategy. The strategy cue card remained on the table as an available reference to the student. Students were provided each math problem on a single piece of paper, as well as the self-efficacy cue card, at the start of each of the three iterations of the task. Additionally, students in the SRPF condition were provided a self-recording form following each of the three math problems. Finally, all students were shown the two posttest problems on a single piece of paper at the end of the session. A basic calculator and pencil was provided to each student to perform the task. An audio recorder was used to record all sessions to facilitate the verbatim recording of open-ended SRL responses.

Design and Procedures

This study adhered to a posttest only control group design. The 60 participants were systematically assigned to one of three conditions: EXPF, SRPF, and a control group. Systematic assignment was used to partition the sample with more precise estimates for students' level of math achievement and math teacher between the three conditions (i.e., SRPF, EXPF, control group). The sample was systematically assigned to conditions based on these factors because of their potential influence on students' math performance and self-regulation strategies. This ensured that each condition contained equivalent numbers of students with lower math achievement (e.g., as defined by a B+ or lower Midterm grade or Algebra II Fall 2014 course grade) and each condition contained an equivalent portion of students taught by each of the four teachers.

Participants who were enrolled in one of the seven Algebra II sections and met inclusionary criteria were invited to participate in this study. Parental informed consent was obtained in order for students to be eligible for participation. Upon receiving parental consent, informed student assent was requested (see Appendix D). After students provided informed assent, participating students engaged in one individualized assessment session with the examiner lasting approximately 45 minutes, the length of one class period at the indicated high school. The study procedures were completed during the school day. Scheduling of sessions was coordinated with the participant's schedule, in order to minimize disruptions to the participants' school day. The primary researcher or an IRB approved and trained assistant researcher conducted all assessments.

Participants across all conditions were provided with identical strategy instruction. The first 10 minutes of the session were devoted to instructing students on an MPS strategy and providing them with guided practice opportunities using the strategy. All participants in the experimental groups and the control group received instruction in a simple MPS strategy based on Montague's (1992) cognitive and metacognitive strategy instruction components and the problem-solving strategy utilized in the Self-Regulation Empowerment Program (SREP) problem-solving instruction (Cleary, 2015). The goal of this strategy instruction was to provide all students with the same cognitive framework from which to complete mathematics word problems. The strategy involved helping students reflect on the nature of the problem prior to solving it, develop a plan, and monitor and evaluate the accuracy of their answers. A cue card modeled from prior literature served as a visual cue to remind the students of the important steps within the MPS strategy. The cue card depicted and described the five steps: 1) determine key parts of the question, 2) draw a picture, 3) write out a numerical equation, 4) solve the problem,

5) proofread and check answer (Cleary, 2015; Chung & Tam, 2005; Montague, 2008). First the examiner defined and provided examples of each of the steps of the MPS strategy. Next, the examiner completed one MPS problem and, while doing so, modeled the use of the steps and verbally described use of the steps during that process. Throughout modeling the problem and use of the strategy the examiner stopped and asked the student for any questions in that process. Next, the student was provided an opportunity for guided practice in completing another MPS problem and using the steps to solve that problem with the examiner (see Appendix E for strategy cue card and MPS strategy instruction module). Strategy instruction and guided practice occurred for approximately 10 minutes or until the student could accurately complete the problem by using the five steps on the cue card.

After strategy instruction, all students were engaged in the MPS practice session, which involved solving three MPS questions and answering SRL microanalytic interview (see Figure *2*). Procedures were the same across conditions except for the manipulation of process feedback. The MPS practice session began with all students previewing the first MPS problem. Then, the researcher administered the self-efficacy, goal-setting and strategic planning questions. Then the participant completed the first MPS problem. Next, all students received outcome feedback as the examiner wrote down the accurate solution for the student upon completion of a math problem. This enabled the student to determine if their outcome response was accurate or inaccurate. Following these procedures, students received the feedback manipulations.

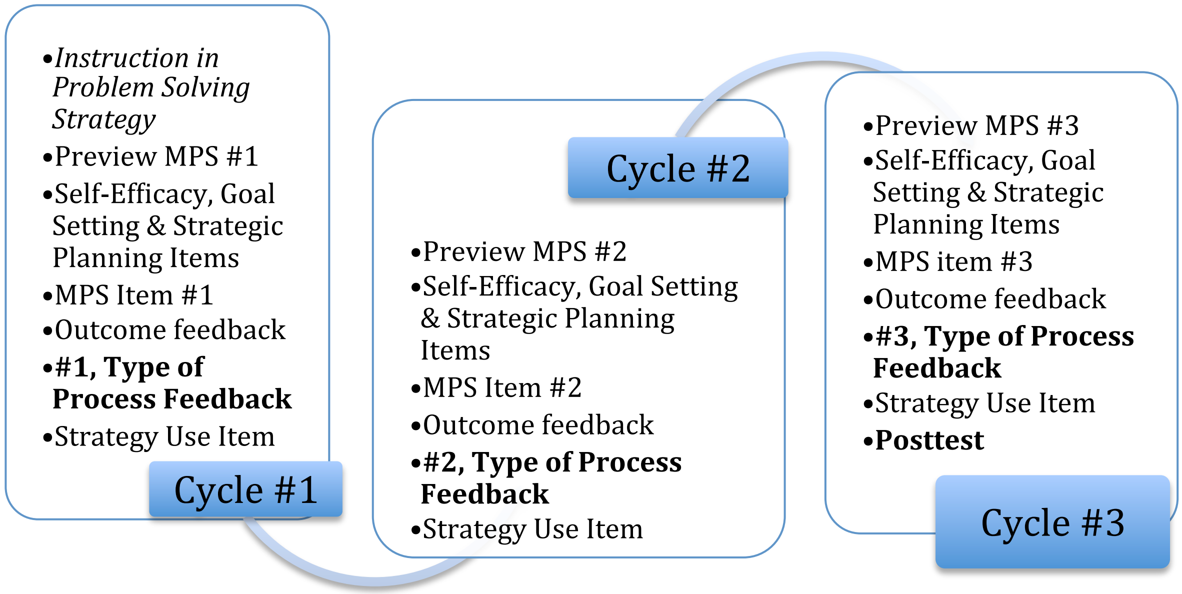

Figure *2.* Assessing Group Differences in Shifts in Self-regulatory Processes and Math Performance Over Three Iterations of the SRL cycle due to Types of Process Feedback

Students assigned to the SRPF condition were guided through steps to generate their own process feedback. Students were instructed how to use a self-recording form to monitor the steps of the 5-step math strategy taught at the beginning of the session. Procedures for this condition have been established by prior research as a way for individuals to self-monitor and provide themselves with process feedback (Cleary et al., 2006). Students recorded the accuracy of their solutions and strategies, as well as steps they used to solve these problems incorrectly or correctly, on the self-recording form (see Appendix E for self-recording form). Students in the SRPF condition used this form after solving each of the three MPS practice problems to self-monitor their own process and use of strategies during the MPS task (Cleary et al., 2006). Specifically, the monitoring form included the following prompts: “Please write down your answer and compare it with the solution provided to you to see if it is correct or incorrect” and “please list the strategies and steps you used to solve this problem.” The form also included a chart directing students to check off whether he or she engaged in certain strategies. This chart also asked students to prioritize which strategies would be the most important ways for the student to improve on future attempts at these math problems. Students completed this form immediately following the completion of a math problem independent of whether they were accurate or inaccurate. The form enabled students to independently generate, self-monitor, and self-record their use of strategies as a way to receive process feedback in comparison to when a learner receives process feedback from an external source, which occurred in the next experimental condition.

Students assigned to the EXPF condition received feedback from the examiner upon students' completion of a problem. The examiner made statements that linked students' performance to the learning process or strategies the student utilized to complete the problem. There was a script of process statements that could be delivered if a student correctly or incorrectly answered a problem; both groups of statements provided feedback that directly linked students' results with specific strategic processes used to complete or understand the MPS practice problems. If the problem was solved correctly, the examiner presented the problem to the student and stated one of the following statements. "You're learning to use the steps", "You're using the steps to solve the problems", "You're getting good at using the steps", or "You're doing well because you followed the steps in order" (Schunk & Swartz, 1993). Therefore, this manipulation involved acknowledging a correct response by attributing performance to the students' strategic process of approaching the problem. If the problem was solved incorrectly, the researcher presented the problem to the student and indicated, "While you're working it helps to keep in mind what you're trying to do. Try to focus on using the steps to solve the problem" or "you need to follow the 5-step math strategy when solving these types of problems" (Schunk & Swartz, 1993). The EXPF connected students' inaccurate performance to the strategy instruction that was first administered; therefore this manipulation put the focus on a process-oriented approach to the way to solve the problem correctly. The examiner simultaneously pointed to the strategy steps on the strategy cue card while delivering the EXPF (see Appendix E for strategy cue card). The students in this condition received feedback three times; following each of the three MPS practice session problems.

The control condition did not receive any type of process feedback; rather these participants received the identical outcome feedback (i.e., the solution of the word problem) that was also provided to both process feedback conditions. After receiving process feedback depending on group assignment, the researcher administered the strategy use microanalytic question.

Next in the MPS practice session, participants previewed the second MPS problem and responded to SRL microanalytic questions about their self-efficacy, goal-setting, and strategic planning for that MPS problem. Then the students engaged in the second MPS problem. Once completed, the student received outcome feedback and either SRPF, EXPF or no feedback about process. Again, feedback was provided according to the assigned experimental condition and accuracy of the students' solution. Following feedback, the researcher administered the SRL microanalytic question for strategy use.

The third iteration within the MPS practice session involved directing the student to preview the third MPS problem and administering self-efficacy, goal-setting, and strategic planning questions. The student then completed the third MPS problem, and feedback was provided according to the above procedures. The strategy use question was administered after the provision of feedback. Overall, in both experimental conditions (i.e., EXPF and SRPF), feedback occurred three times during the MPS practice session directly following students' completion of each of three MPS practice problems.

Following the MPS practice session, the examiner administered two mathematics posttest problems to students in each treatment in order to assess group differences in students' mathematics performance on the same type of math problems. Participants in all three conditions received the same posttest problems, and did not receive any feedback during this posttest. Once participants completed the two posttest problems, the primary researcher ended the MPS practice session.

Results

This chapter examines the results from the data analytic techniques performed. Prior to engaging in statistical analyses to address the research questions, preliminary analyses were conducted including an initial screening of the data (e.g., missing data, outliers). Following the preliminary analyses, descriptive statistics and inferential statistical analyses were conducted to examine the research questions. Analyses of variance (ANOVA) were computed to examine the effects of experimental condition (i.e., SRPF, EXPF, control) on mathematics achievement and self-regulated learning processes. All statistical analyses were performed using IBM SPSS Statistics Premium GradPack 24.

Preliminary Data Analysis

The frequency of missing data, presence of outliers, and linearity and normality of the data was examined before addressing the research questions. Means and standard deviations for all continuous measures were calculated in order to determine the presence of outliers. The results revealed no missing data or outliers. Data screening procedures regarding the normality of data were conducted for the metric self-efficacy variable because it was recorded based on a Likert scale. There was no evidence of problems with skewness or nonnormality.

Descriptive Analyses

Table 2 presents the descriptive statistics (i.e., mean, standard deviations) for background variables for the three conditions, which should have been equated through systematic assignment to condition. The examiner conducted separate ANOVA's to ensure the comparability of the treatment groups across these dependent measures; all of these preliminary ANOVA's were nonsignificant.

Table 2

Demographic Variables by Treatment Condition

Measure	SRPF (n=20)		EXPF (n=20)		Control (n=20)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Midterm grade	76.66	13.0	76.08	16.13	78.83	14.27
GPA	3.25	0.66	3.18	0.54	3.22	0.54
Age of students	15.80	0.52	16.00	0.65	15.75	0.72
Grade level	9.95	0.22	10.15	0.37	10.05	0.51

Analyses were conducted on the last item for all continuous dependent measures (i.e., the third question for self-efficacy, goal-setting, strategic planning, strategy use, MPS practice problem, and the second problem for MPS posttest; see Table 3). By analyzing the final data point of these dependent measures, this ensured that students had received the feedback intervention the maximum amount of times prior to this data collection.

Table 3

Means and Standard Deviations Across Dependent Measures by Treatment Group

Measure	SRPF (*n*=20)		EXPF (*n*=20)		Control (*n*=20)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Self-efficacy	80.00	15.89	84.00	18.18	78.00	19.62
Goal-setting	1.00	0.32	0.85	0.49	1.15	0.59
Strategic planning	1.85	1.49	1.20	1.15	1.30	1.13
Strategy use	1.54	0.34	3.60	1.76	3.40	1.76
MPS practice problem	2.65	0.67	2.43	0.91	2.75	0.73
MPS posttest problem	1.88	0.93	1.98	1.16	1.55	1.10

Note: Means were based on a Likert scale from 10 to 100 for self-efficacy, 0 to 3 for goal-setting, 0 to 15 for strategic planning and strategy use, 0 to 3 for MPS problems (see Appendix F and G). MPS = Math Problem Solving. Refers to the third question for self-efficacy, goal-setting, strategic planning, strategy use, MPS practice problem, and the second problem for MPS posttest problem.

Table 4 presents the correlations among all key dependent variables used in the study. Results indicated significant positive correlations between self-efficacy and several other measures: strategic planning, MPS practice problem, and MPS posttest problem. This positive relationship suggests that as students' self-efficacy score increased, so did their score for strategic planning, MPS performance within the MPS session, and MPS posttest performance. Results also indicated a significant positive correlation between strategy use and both the MPS practice problem and MPS posttest problem. The relationship between the MPS posttest problem and the MPS practice problem measures were of medium size (*r* = .354).

Table 4

Correlation Matrix of Dependent Measures

Measure	1	2	3	4	5	6
1. Self-efficacy	-					
2. Goal-setting	.000	-				
3. Strategic planning	.268*	.109	-			
4. Strategy use	.098	.167	.168	-		
5. MPS practice problem	.442**	-.045	.069	.304*	-	
6. MPS posttest problem	.470**	-.049	.247	.273*	.354**	-

$^*p<.05$. $^{**}p<.01$.

Group Differences in SRL and Achievement

Research Question 1: Are there statistically significant differences among feedback groups (i.e., SRPF, EXPF, and control) in terms of self-regulated learning processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use)?

In order to analyze the first research question, separate two-way ANOVAs were conducted that examined the effect of feedback group (i.e., SRPF, EXPF, and control) on students' self-report of the SRL dependent variables (i.e., self-efficacy, goal-setting, strategic planning, and strategy use). Given that midterm grade was used to systematically assign students to intervention conditions, it was included in the 3 x 2 ANOVA as a crossing variable. Of interest in all analyses was the main effect for treatment condition and the interaction effect. As noted earlier, means and standard deviations for all scale scores across feedback groups are reported in Table 3 and refer to the descriptive statistics for item 3 for each of these variables. Two-way ANOVA results revealed no statistically significant treatment group differences across the microanalytic self-regulation outcomes including goal-setting, strategic planning, and strategy use (see Table 5). However, there was a statistically significant interaction between the effects of Midterm grade and feedback condition on students' self-report of self-efficacy, $F(2, 60) = 5.398$, $p=.007$, $\eta_p^2 = .167$ (see Table 5). This interaction effect indicates that the effect of treatment group on self-efficacy depended on the achievement levels of participants. To understand the impact of the treatment condition on students' self-efficacy, it is important to know whether the student is high or low achieving. Therefore these results indicate that the impact of treatment condition depended on students' MPS achievement level. A follow-up test was conducted due to the significant interaction effect in which the file was split by prior achievement and a one-way ANOVA of treatment condition on self-efficacy was conducted. Results were nonsignificant for low achieving students, however, there was a statistically significant difference between feedback groups for high achieving students' self-report of self-efficacy, $F(2, 30) = 4.155$, $p=.026$. Tukey post hoc analyses demonstrated that high achieving students in the EXPF condition reported higher self-efficacy ($M = 92.73$) than students in the SRPF condition ($M = 76.00$; $p = .026$). There were no significant differences between students in the EXPF condition and control condition, or between students in the SRPF condition and control condition.

Table 5

Two-Way ANOVA Results Examining Group Differences in Self-Regulated Learning Processes

Measure	*Source*	*SS*	*df*	*MS*	*F*	*p*
Self-efficacy	Midterm Grade	1852.355	1	1852.355	7.249	.009
	Condition	255.129	2	127.565	.499	.610
	Interaction Effect	2758.607	2	1379.304	5.398	.007*
	Total	409200.000	50			
Goal-setting	Midterm Grade	.047	1	.047	.200	.657
	Condition	.935	2	.468	1.978	.148
	Interaction Effect	.287	2	.144	.607	.549
	Total	74.000	60			
Strategic planning	Midterm Grade	7.088	1	7.088	4.518	.038
	Condition	5.179	2	2.589	1.651	.201
	Interaction Effect	.138	2	.069	.044	.957
	Total	223.000	60			
Strategy use	Midterm Grade	11.938	1	11.938	5.993	.018
	Condition	.382	2	.191	.096	.909
	Interaction Effect	5.022	2	2.511	1.260	.292
	Total	860.000	60			

Note: Two-way ANOVAs examine the effect of Midterm exam and the three types of feedback groups including SRPF, EXPF, and the control group. Refers to third question for self-efficacy, goal-setting, strategic planning, and strategy use.
ANOVA = Analysis of variance.
$^*p < .05$.

Research Question 2: Are there statistically significant differences among feedback groups (i.e., SRPF, EXPF, and control) in terms of mathematics performance (i.e., as measured by MPS practice problems and posttest problems)?

To address the second research question, separate two-way ANOVAs were conducted that examined the effects feedback group (i.e., SRPF, EXPF, and control) on students' mathematics outcomes (i.e., MPS practice problem and MPS posttest problem). Given that midterm grade was used to systematically assign students to intervention conditions, it was included in the 3 x 2 ANOVA as a crossing variable. Of interest in all analyses was the main effect for treatment condition and the interaction effect. Again, means and standard deviations for all scale scores of mathematical performance across treatment groups are reported in Table 3.

The two-way ANOVA results revealed no statistically significant main effects of treatment condition or interactions across either of the mathematics outcome variables (i.e., MPS practice problem and MPS posttest problem; see Table 6).

Table 6

Two-Way ANOVA Results Examining Group Differences in Math Performance

Measure	*Source*	*SS*	*df*	*MS*	*F*	*p*
MPS practice problem	Midterm Grade	2.281	1	2.281	3.978	.051
	Condition	1.361	2	.681	1.187	.313
	Interaction Effect	1.214	2	.607	1.059	.354
	Total	443.750	60			
MPS posttest problem	Midterm Grade	26.894	1	26.894	40.698	.000
	Condition	1.434	2	1.309	1.981	.148
	Interaction Effect	2.619	2	1.309	1.981	.148
	Total	261.500	60			

Note: Refers to third problem for MPS practice problem and the second problem for MPS posttest problem. *$p < .05$. ANOVA = Analysis of variance.

Research Question 3: Are there statistically significant shifts in self-regulatory processes within each of the feedback groups (i.e., SRPF, EXPF, and control)?

To address the third research question, repeated measures ANOVAs were conducted for three of the SRL processes (i.e., goal-setting, strategic planning, and strategy use). For each of these analyses, three time points were used. The results of the repeated measures ANOVAs for each treatment condition are presented in Tables 7, 8, and 9, respectively.

For the SRPF group, the results showed that there were no significant shifts observed for any of the SRL processes (see Table 7).

Table 7

Shifts in Self-Regulated Learning Processes for the SRPF Group

Measure	*M*	*SD*	*Source*	*SS*	*df*	*MS*	*F*	*p*
Goal-setting			Within-subjects effects	0.033	2	.017	.241	.787
Goal-setting question 1	1.00	.46						
Goal-setting question 2	.95	.22						
Goal-setting question 3	1.00	.32						
Strategic planning			Within-subjects effects	2.533	2	1.267	1.142	.330
Strategic planning question 1	1.55	1.05						
Strategic planning question 2	1.35	1.23						
Strategic planning question 3	1.85	1.50						
Strategy use			Within-subjects effects	.400	2	.200	.269	.766
Strategy use question 1	3.60	1.57						
Strategy use question 2	3.70	1.38						
Strategy use question 3	3.50	1.54						

**p*<.05. Repeated Measure ANOVA

For the EXPF group, the results showed that there were no significant shifts observed for any of the SRL processes (see Table 8). The results for strategy use narrowly missed the a priori statistical significance level of .05 ($F(2, 20) = 6.533$, p=.057, $\eta^2 = .140$). The effect size for the observed shift was large.

Table 8

Shifts in Self-Regulated Learning Processes for the EXPF Group

Measure	*M*	*SD*	*Source*	*SS*	*df*	*MS*	*F*	*p*
Goal-setting			Within-subjects effects	.233	2	.117	.769	.471
Goal-setting question 1	.70	.47						
Goal-setting question 2	.80	.41						
Goal-setting question 3	.85	.49						
Strategic planning			Within-subjects effects	.033	2	.017	.015	.985
Strategic planning question 1	1.25	1.12						
Strategic planning question 2	1.25	1.21						
Strategic planning question 3	1.20	1.15						
Strategy use			Within-subjects effects	6.533	2	3.267	3.093	.057
Strategy use question 1	3.30	1.46						
Strategy use question 2	2.80	1.36						
Strategy use question 3	3.60	1.05						

**p*<.05. Repeated Measure ANOVA

Finally, Table 9 summarizes the results of the Repeated Measures ANOVAs conducted within the control group, as well as the descriptive statistics for each of the SRL processes analyzed. For the control group, the results showed that there were no significant shifts occurring within each SRL process with the exception of goal-setting. The results indicated a statistically significant linear trend with respect to positive shifts in goal-setting over time for the control group ($F(2, 20) = 5.783$, p=.006, $\eta^2 = .233$). The effect size for the observed shift was very large.

Table 9

Shifts in Self-Regulated Learning Processes for the Control Group

Measure	*M*	*SD*	*Source*	*SS*	*df*	*MS*	*F*	*p*
Goal-setting			Within-subjects effects	.933	2	.467	5.783	.006*
Goal-setting question 1	.85	.49						
Goal-setting question 2	.95	.39						
Goal-setting question 3	1.15	.59						
Strategic planning			Within-subjects effects	.100	2	.050	.045	.956
Strategic planning question 1	1.25	1.07						
Strategic planning question 2	1.35	1.23						
Strategic planning question 3	1.30	.13						
Strategy use			Within-subjects effects	4.300	2	2.150	2.129	.133
Strategy use question 1	3.80	1.32						
Strategy use question 2	3.15	1.35						
Strategy use question 3	3.40	1.76						

*p<.05. Repeated Measure ANOVA

Discussion

The key purposes of this dissertation were to assess: (a) differential effects of process feedback conditions on SRL processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) and mathematics performance (MPS practice problem and MPS posttest problems), and (b) shifts in regulatory processes within each treatment condition. The focus and objectives of this study were important for several reasons. First, this study sought to expand the feedback literature by examining the effects of different types of process feedback (i.e., SRPF and EXPF) on students' situation-specific SRL processes, including self-efficacy, goal-setting, strategic planning, and strategy use, as measured with SRL microanalytic methodology (Cleary et al., 2015). Given the paucity of studies examining the differential effects of various types of process feedback (Butler & Winne, 1995; Cleary et al., 2015; Hattie & Timperley, 2007; Schunk & Rice, 1993; Schunk, 1983), this study attempted to address this gap. This study also utilized contextualized methodology, SRL microanalysis, to conduct a more nuanced examination of the link between feedback during a mathematics practice session and shifts in students' regulatory reactions within that context (Butler & Winne, 1995; Cleary, 2011; Cleary et al., 2015; Hattie & Timperley, 2007).

This study also explored whether SRPF and EXPF have varying effects on students' MPS skills. Several researchers have identified the need to examine how feedback functions relative to higher-order learning tasks, such as the complex task of problem-solving (Fernandez & Hadaway, 1993; Gibbs & Simpson, 2005, Mory, 2003, Nicol & Macfarlane-Dick, 2006). Though research has documented a strong connection between SRL and various positive academic outcomes, this study aimed to add to the existing information on the relationship between types of process feedback and MPS (De Corte, Mason, Depaepe, & Verschaffel, 2011; De Corte, Verschaffel, & Op't Eynde, 2000; Kitsantas, 2002; Schunk & Zimmerman, 1998).

Another important potential contribution was that this dissertation investigated shifts in students' SRL processes as students engage during the MPS activity. There is some current literature indicating that SRPF produces adaptive shifts in SRL processes such as self-efficacy (Hattie & Timperley, 2007); however, it was less clear about how different types of process feedback may change students' SRL processes during the process of learning.

Contrary to the hypotheses, students in the three conditions did not differ significantly in SRL processes or MPS performance. Therefore students in the SRPF condition did not show distinct SRL processes or MPS performance relative to students in the EXPF condition or the control. Students in the SRPF condition did not exhibit more adaptive shifts in SRL processes throughout the practice session. In fact, significant group differences were not found between EXPF, SRPF, and control groups in terms of MPS performance, SRL processes, or shifts in SRL processes. In the following sections, I will discuss and interpret these findings relative to the current literature.

Feedback Group Differences across SRL and Achievement

The first and second research questions examined feedback group differences (i.e., SRPF, EXPF, and control) in mathematics performance during the practice session and at posttest, and differences across several SRL processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use). It was expected that students receiving SRPF would exhibit significantly higher MPS performance and engagement in SRL processes in comparison to students in the control or EXPF condition. It was also expected that students receiving EXPF would display higher MPS performance and SRL engagement relative to control students. The results revealed no statistically significant group differences across MPS achievement measures or SRL processes. However, there was a statistically significant interaction between the effects of Midterm grade and feedback condition on students' self-report of self-efficacy (see Table 5). This indicates that the effect of feedback condition on self-efficacy differed depending on a student's level of prior achievement. Further analyses indicated high achieving students in the EXPF condition demonstrated significantly higher self-reported self-efficacy in comparison to students in the SRPF condition.

This set of null findings was unexpected given the research showing that process-related feedback can significantly support self-regulation and therefore academic performance (Labuhn, Zimmerman, Hasselhorn, 2010). Overall, studies have indicated that learning with feedback is preferable to learning without feedback (McDaniel & Fisher, 1991; Zellermayer et al., 1991), and process feedback more successfully affects mathematical reasoning performance than outcome feedback (Kramarski & Zeichner, 2001). The study's null findings were also unexpected in the context of literature supporting the connection between students self-generating their own feedback through self-recording and increases in self-regulatory engagement such as improved self-efficacy for the task (Earley et al., 1990). SRPF has been shown to promote self-regulation in that it is a higher order and more advanced way to provide strategic feedback (Shute, 2008). Research shows SRPF motivates learners' behavior, increases self-efficacy beliefs, and provides deliberate attention to specific aspects of one's behavior towards facilitating the learning process and attenuating the learner to specific strategies that should enhance achievement (Mace, Belfiore, & Shea, 1989; Schunk & Zimmerman, 1997). The delivery of EXPF has also been shown to have a positive effect on individual development of self-efficacy for a task because this type of feedback informs students of their capabilities and progress in learning, which functions to motivate students to continue to perform well (Geister, Konradt, & Hertel, 2006; Schunk & Pajares, 2002). EXPF has been identified as a relevant way to enhance self-regulation processes (Sandars & Timothy, 2011).

There are several potential reasons why the hypotheses were not confirmed, including the strength of the manipulation and a couple of methodological limitations. First, it appears that the difficulty level of the mathematics problems may not have been sufficiently challenging to engender an environment in which students would use feedback. Second, the duration of the study may have been insufficient given the overall complexity of the problem-solving required. The complex nature of MPS may require more detailed feedback delivery than the manipulation implemented. Another potential reason why the hypotheses were not confirmed was the general strength of the feedback manipulations of SRPF and EXPF. Also, failure to randomly assign participants to conditions within the blocking variable of Midterm grade could have affected the validity of the statistical analyses and may have affected variability. Finally, if the effect was smaller than expected, then statistical power within the current dissertation may not have been adequate to detect the effect.

In terms of MPS problem difficulty, inspection of the means for self-efficacy and MPS performance across each experimental condition showed that students demonstrated generally high self-efficacy and high level of MPS performance (see Table 10). Specifically, students were very confident (high self-efficacy) in their ability to correctly solve the MPS problems from the start of the task through the end of the session. In addition, students performed very well from the first MPS problem throughout the task, with the exception of students generally exhibiting more difficulty on the second posttest problem. This demonstrates the MPS problems were very easy for the overall study population. Given the apparent presence of a ceiling effect, it is not surprising that the students' MPS achievement across any of the groups failed to improve, nor was it surprising students did not change their engagement in SRL processes. These findings confirm a basic premise in the conceptualization of self-regulation that when tasks are easy, students will not need to engage in regulatory processes. That is, they will be less likely to adapt regulatory strategies because they are already succeeding. It is when students are presented with challenges or obstacles that they need to deploy strategic and regulatory thinking and action (Bandura, 1997; Usher & Pajares, 2008). Likewise, Ramdass and Zimmerman (2011) indicated that adequately challenging and interesting assignments foster the development of students' motivation and self-regulation skills toward academic success. SRL processes have been shown to be necessary and valuable in the face of a challenging task, and in the context of a more challenging set of MPS problems, this study may have provided more information on the effects of SRPF or EXPF on SRL processes and MPS achievement.

Table 10

Means for Self-Efficacy and MPS Performance

	Means by Experimental Condition		
Dependent Measures	SRPF Condition	EXPF Condition	Control Condition
Self-Efficacy Question #1	73.5	81	77.5
Self-Efficacy Question #2	78	83	79.5
Self-Efficacy Question #3	80	84	78
MPS Practice Problem #1	2.28	2.18	2.38
MPS Practice Problem #2	2.68	2.52	2.63
MPS Practice Problem #3	2.65	2.42	2.75
MPS Posttest #1	2.58	2.40	2.73
MPS Posttest #2	1.88	1.98	1.55

Note: Self-efficacy range of score based on Likert scale of 10 to 100. MPS scores based on coding in which students could earn 0 to 3 points.

The null findings may also have been due to the difficulty level of the MPS problems. Kulhavy and Stock's (1989) feedback model indicates that when students have high confidence that their answer will be correct, and they learn their response is correct, students spend less time studying feedback (Kulhavy, 1977). In this case, when students have high self-efficacy for a task and are able to provide accurate responses, they have low need for extensive or elaborate feedback. However, when students are highly confident in their correct response and feedback indicates their product was incorrect, students will exert high effort to study the feedback to adapt future behaviors. Kulhavy and Stock's (1989) model suggests that if students in the current study had high confidence in their ability to complete the presented MPS problems, and subsequently were successful in the MPS problems, there would be a natural decrease of time and effort spent in studying provided feedback for error correction. Therefore, the implementation of SRPF and EXPF may have shown more influence on MPS performance if students initially were confident in their ability to perform the task (e.g., exhibited high self-efficacy), but the task was more challenging and students were initially less successful. Hattie (2012) indicates that student learning often comes from instruction that is appropriately challenging due to its relationship with engagement. The current study attempted to ensure difficulty level of the problems by working with a teacher at the target high school to create MPS problems that would both challenge students, and that included material for which students had sufficient exposure to the math operations that the MPS problems required. Pilot testing was also completed to administer problems and ensure the clarity of procedures. Problems were also discussed with a researcher, Dr. Callan, who has studied the assessment of SRL through MPS problems. However, it appears that these methods were insufficient to ensure problems were sufficiently challenging.

Regardless of whether or not mathematics problem difficulty was a primary reason underlying the null findings, other potential reasons exist. The design of this study was fairly narrow in scope and duration, particularly when considering the complexity of the MPS task. MPS is a complex task that requires students to engage in multiple steps and processes. Hattie and Timperley (2007) indicate that feedback has been shown to be more effective with low task complexity. It is possible that the feedback manipulations would have had some effect during this short duration study if students were asked to engage in a simpler task, such as basic operation skills for addition or subtraction. For example, Ramdass and Zimmerman (2008) provided a math intervention of strategy instruction and practice within a similar time frame of 45-50 minutes; however, the task involved solving four math long division problems. Ramdass and Zimmerman (2008) demonstrated fifth and sixth grade students receiving strategy training displayed higher math division performance than control students. The division problems used by Ramdass and Zimmerman (2008) were simpler than the MPS problems used in the current study for several reasons. The division problems required by Ramdass and Zimmerman (2008) involved simple calculation skills. The MPS problems in the current dissertation required students to engage in multiple steps such as interpreting a word problem, visualizing the problem, identifying what the learner needs to do, and carrying out calculations correctly. Therefore, it is possible that the effects of an intervention may vary depending on the nature of the task that students are asked to complete.

Other research examining MPS interventions have been successful in demonstrating growth in MPS performance through long-term interventions. In these studies, students are provided multiple opportunities to learn a strategy and apply it within the given context. For example, Montague, Krawec, Enders, and Dietz (2014) implemented a problem-solving intervention with forty middle schools over the course of 8 months and demonstrated a significantly greater rate of growth on curriculum-based measures than students in the comparison group that did not receive this strategy within the complex academic area of MPS. This type of long-term intervention contrasts with the intervention used in the current study in that the latter provided one session of approximately 10 minutes of guided instruction in the MPS strategy and 30 minutes of practice with the strategy during the intervention of SRPF or EXPF. Strategy instruction included one example of modeling and one guided practice opportunity for students to use the 5-step MPS strategy. Students practiced the MPS strategy on the same type of MPS problem rather than gaining the opportunity to generalize that practice to a different type of MPS problem. Because students did not have the opportunity to generalize use of the strategy to other types of problems and only had minimal time to practice the strategy, it seems reasonable to speculate that students may have had difficulty interpreting and creating meaning for the process feedback. A brief training experience may be appropriate for simpler academic tasks, such as division (Ramdass & Zimmerman, 2008) or more concrete motoric tasks such as free throw practice (Cleary et al., 2006), but may not be sufficient for a complex task like mathematics problem-solving (Montague et al., 2014).

It is also possible that the limited duration of the current intervention, within the context of a complex task like MPS, negatively affected possible results for SRL processes. In their short-term strategy training intervention, Ramdass and Zimmerman (2008) did not improve students' SRL processes of self-efficacy and self-evaluation. Similarly, the current dissertation did not demonstrate significant improvements in the studied SRL processes across the short-term intervention with the exception of the high achieving students in the EXPF condition reporting significantly higher self-efficacy than students in the SRPF condition. Conversely, Nietfeld et al.

(2006) demonstrated changes in SRL processes following longer-term practice with the MPS strategy and SRPF. Nietfeld et al. (2006) provided an SRPF intervention over a 16-week undergraduate course of educational psychology and demonstrated adaptive changes in SRL processes as students engaged in SRPF over time. In retrospect, it appears that students in the current study may not have had enough time to learn the MPS strategy, engage in self-recording, and then use that feedback in productive ways to improve performance. Although speculative, it is possible that if the current study's feedback manipulation was coupled with extended practice opportunities, some achievement or SRL differences might have emerged.

A third possible reason that the predicted effects on SRL processes and MPS performance did not emerge in this study may be the lack of clarity and insufficient overall strength of the SRPF and EXPF manipulations. For example, the EXPF manipulation lacked specificity. In the current study, when students answered a problem incorrectly the EXPF response may have been, "You need to follow the 5-step math strategy when solving these types of problems." The script for EXPF (see Table 11) did not precisely point out a certain step that students should improve. Similarly, the script for correct responses did not directly indicate what steps the student used correctly, rather the EXPF generally attributed student success to the 5-step strategy (see Table 11). Though the EXPF manipulation was based on prior research (Schunk & Swartz, 1993), additional research indicates that effective EXPF includes information about what students did well, what they need to improve, and steps they can take to improve their work (Black & William, 1998; Hattie & Timperley, 2007; Sadler, 1998). The EXPF manipulation emphasized what students did well when students solved a problem correctly, and highlighted what they need to improve when a problem was solved incorrectly (see Table 11). However, the EXPF scripts may have been too general and not tailored specifically to each student's responses. Research emphasizes that EXPF is significantly more effective when it provides the learner with details on how to improve an answer or response (Bangert-Drowns, et al., 1991; Pridemore & Klein, 1995; Shute, 2008; Williams, 1997). In particular, students report wanting specific, detailed feedback for mathematics (Rice, Mousley, & Davis, 1994). When feedback lacks specificity, students may view it as useless, which can negatively impact future learning (Kluger & DeNisi, 1996; Sweller, Van Merrienboer, & Paas, 1998) or their motivation to continue the task (Ashford, 1986).

Table 11

Script for EXPF Manipulation Used in Current Study

If the problem is solved correctly:	If problem is solved incorrectly:
"You're learning to use the steps" "You're using the steps to solve the problems" "You're getting good at using the steps" "You're doing well because you followed the steps in order"	"While you're working it helps to keep in mind what you're trying to do. Try to focus on using the steps to solve the problem" "You need to follow the 5-step math strategy when solving these types of problems."

(Adapted from Schunk & Swartz, 1993)

Merry and Orsmond (2008) conducted a study wherein students received EXPF through audio files of tutors' spoken feedback sent to students as an e-mail attachment. The audio files represented EXPF because it focused on engaging students in thinking and strategies. Merry and Orsmond (2008) attributed some of the success of the audio process feedback (i.e., student learning was enhanced through audio file feedback) to the feedback variation observed by students in the tone of the tutors' voice which helped students discern the most important aspects of the feedback. This nuanced aspect of feedback may not have been apparent in the feedback provided to students in the current study. The EXPF statements were all provided in a neutral tone independent of whether EXPF was positive or negative. In addition, authors note that students appreciated the detail enhanced in audio file feedback as opposed to written feedback (Merry & Osmond, 2008), which coincides with Lea and Street (1998) indicating that brief feedback comments may have less significant meaning to students as opposed to more detailed feedback. In short, the EXPF provided in the current study was simple and did not vary between mathematics problems. That is, students received a prescribed type of EXPF based on a pre-determined script.

Another potential issue was students' lack of understanding of the feedback manipulations. Gibbs and Simpson (2005) indicated that feedback may be less effective if students do not understand the function of the feedback, and therefore are not able to interpret the feedback. For example, the purposes of the feedback types in this study were as follows: outcome feedback aimed to correct errors, EXPF aimed to promote the development of skills by focusing on evidence of students' strategy use rather than content, and SRPF aimed to promote meta-cognitive self-monitoring by promoting students' reflection on learning processes in the MPS task (Gibbs & Simpson, 2005). Feedback has also been shown to be less effective when it is not specific in its aspirations for student effort (Gibbs & Simpson, 2005); the EXPF generally indicated students should focus on the strategies from the strategy instruction while completing the problem (see Table 11). It is possible that if this feedback was further tailored and specified for students' task completion, or more directly explained the purpose of each type of feedback, the manipulation may have had a more powerful impact.

In terms of the SRPF condition, students were asked to record strategies used during MPS and to indicate areas for improvement through a self-monitoring form adapted from prior research (see Table 12). This type of feedback was more specific and individualized than the EXPF manipulation as students self-generated their own feedback based on their personal experiences with the practice mathematics problems (Gibbs & Simpson, 2005). The SRPF also linked to prior research as the chart and questions led students in error analysis. The self-reflective components of the SRPF form systematically guided students through a metacognitive process to learn about one's mistakes and recycle that knowledge for future strategic improvement (Hartman, 2001). However, the current study did not train students in use of the SRPF form.

Table 12

Form for SRPF Manipulation Implemented in Current Study

1. Please write down your answer and compare it with the solution provided to you to see if it is correct or incorrect.
2. Please list the strategies and steps you used to solve this problem.
3. Complete the following two columns for the problem that you got incorrect.

Why do you think you got this problem wrong?	**Check all that apply**	**What do you think are the most important ways for you to improve?**
1. I did not check my work		
2. I did not draw a diagram.		
3. I did not look at all possible choices		
4. I did not understand the problem		
5. I made a silly calculation mistake		
6. I missed one of the steps to solve the problem correctly		
7. Other (write out your answer)		
8. I did not show my work		

(Adapted from Cleary et al., 2006)

The current study's lack of explicit training and instruction in how to fill out and utilize the SRPF form may have lessened the impact of the SRPF manipulation on MPS performance or SRL performance. Cleary et al. (2006) demonstrated positive effects of SRPF with college students' acquiring a novel motoric skill. In that study, the self-recording feedback form included similar information to the one used in the current study (see Table 11) as it asked students to self-reflect on the performance, reasons for missed shots, and strategies needed for future performance. The intervention effects observed in Cleary et al. (2006) may have been partially due to the provision of an additional training component wherein students were taught how to use the self-recording feedback form and the examiner modeled use of the SRPF (Cleary et al., 2006), whereas the current study did not include training in using the SRPF provided.

With limited research in this domain, it would be useful to account for these possible limitations and continue to examine the differential relationship between SRPF and EXPF with MPS performance and SRL processes to better understand the role of these two types of feedback with regard to facilitating students' self-regulation and achievement during academic tasks.

Analysis of Shifts in SRL Processes Within Feedback Groups

For the third research question, the author examined potential shifts in students' microanalytic self-regulatory processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) within each treatment condition (i.e., SRPF, EXPF, and control). Cleary et al. (2015) was the first study to use SRL microanalysis to examine shifts in student SRL following feedback. In that study, however, the authors only employed a very simple outcome feedback statement. In the current dissertation study, although all three conditions received outcome feedback (i.e., how they performed on the mathematics problems), the experimental conditions also received one of two types of process feedback. The current study expanded on the work by Cleary et al. (2015) by providing SRPF or EXPF and by using SRL microanalytic assessment methodology to track student SRL on several occasions during the practice session. It also went a step further by examining the differential effects of two types of process feedback on SRL shifts during an academic task. Though this was exploratory in nature, it was expected that students in SRPF and EXPF conditions would demonstrate greater adaptive shifts in SRL processes relative to control students.

Exploratory results revealed no statistically significant shifts in any SRL process (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) for the SRPF and EXPF conditions. Overall, the control group lacked evidence of shifts in SRL processes with the exception of demonstrating a significant shift in the quality of their goal-setting.

It was expected that as SRL processes grew in response to SRPF or EXPF, the SRL processes would have an interdependent effect on each other, as predicted by Zimmerman's (2000) cyclical model. This prediction was also based on assumption that SRL would increase achievement; however, because there was no shifting in SRL, the potential achievement gains were also minimized. It was anticipated that as one of these SRL processes is systematically enhanced, others are also increased. For example, students with high self-efficacy have been shown to set higher goals, use more effective SRL strategies, monitor their work more efficiently, and persevere in academic challenges (Schunk & Meece, 2006; Zimmerman & Schunk, 2008).

Similarly, as mentioned previously, there is no need for learners to shift their strategic SRL processes when they are performing well on an academic task as occurred in the current study. Defective forms of self-regulation (i.e., failure to exert self-control) include situations when a learner does not exert the effort to control oneself and engage in SRL processes (Baumeister & Heatherton, 1996). Failure to self-regulate can occur in response to inappropriate standards that are too high or too low (Baumeister & Heatherton, 1996; Heatherton & Ambady, 1993). These findings confirm that regulation is most useful when students are appropriately challenged. A difficult task with standards that appropriately fit the population provides the rationale and stimulus for learners to engage in regulation, such as adjusting processes to try to achieve a goal through adapting strategies, monitoring oneself, or studying feedback.

Given the exploratory nature of this research question and that there are very few studies that examined shifts in SRL over time, it is challenging to definitively explain the null findings. However, future research should take into account the nature of the methodology and difficulty of the academic task, as well as the factors discussed in the prior section with regard to strength of the feedback manipulation, when assessing for the impact of feedback on shifts in SRL within a discrete task.

Limitations and Areas for Future Research

As discussed in the previous section, there were a few methodological limitations that may have undermined the results. These include the difficulty level of the mathematics problems, short duration of the strategy training, and limited practice opportunities.

Study findings may have been limited due to the mismatch of the difficulty level of MPS problems and the skill level of the students. Future research can accommodate this limitation by going through steps to ensure MPS problems are adequately challenging for the target population. Though the current author worked with an expert to create MPS problems and completed pilot testing to ensure the clarity of procedures, in retrospect, additional pilot testing may have been useful to ensure the difficulty level of problems by conducting pilot testing with students from the target population to assess whether they accurately completed the math problems throughout the task. Future research would benefit from conducting a more rigorous assessment measures of students' prior skills in MPS. The inclusion of a pretest of MPS knowledge to ensure knowledge of students' prior levels of achievement and dispositions in MPS would be critical to avoiding this methodological weakness (Hattie, 2012).

It would also be beneficial for future research to include multiple conditions that receive MPS problems according to a range of difficulty. Given the current study demonstrated a lack of significant differences in MPS performance and SRL processes across three groups that encountered overly easy MPS problems, future research could build on this by comparing conditions receiving easier or more difficult MPS problems to assess for differences in whether learners adapt or not across conditions.

Another limitation was that participants were recruited from a single school within a single geographical location limits the ability to generalize findings to other adolescent populations. Similarly, due to the voluntary nature of the study it is possible that students self-selected into the study who were more capable and confident in their MPS skills. Future research may include full classrooms of students in order to ensure a broad range of learners with varying degrees of confidence or self-efficacy in their MPS abilities. More specifically, the sample primarily consisted of students who identified as Caucasian/White. Furthermore, the sample does not represent students from low socioeconomic status as only 5% of the sample received reduced price or free lunch. Therefore, this sample may not represent more diverse populations or those of ethnic or economic minority groups. Finally, with regard to sample and design, the current study failed to correctly implement block random assignment of participants to conditions and instead used systematic assignment as a strategy intended to create groups with equivalent numbers of high and low achieving students. Future research needs to either use simple random assignment of participants to treatment conditions and control nuisance variables such as prior achievement by including them as covariates in the analyses or use random assignment within blocks or levels of the nuisance variable (such as high or low prior achievement) in order to ensure the validity of the statistical analyses is maintained. In addition, the statistical power achieved within the current dissertation design may not have been adequate to detect effects if they were smaller than expected, and future research may accommodate this limitation by increasing power such as through recruitment of a larger sample.

As discussed, it is possible that students did not have enough time and practice to benefit from the manipulations given the complex nature of MPS. If students did not receive sufficient training in the MPS strategy, this would have undercut effects of the SRPF or EXPF interventions on MPS performance or SRL processes. Future studies might lengthen the MPS strategy instruction in order to provide greater impact on SRL engagement throughout the following session. This may involve engaging students in multiple practice sessions that incorporate the process feedback manipulations, particularly because MPS can be quite a challenging activity. Results show that direct strategy instruction improves student performance, but that students are less likely to incorporate SRL strategies into their academic routine without guided and independent practice (Lee, McInerney, & Liem, 2010). The strategy instruction provided in the current study provided a limited amount of guided practice for the one MPS problem. The overall complexity of the problem-solving required in the study may require several practice sessions for performance improvement rather than the current short-term practice session. In addition, it may have been beneficial for future SRL engagement and academic achievement to provide extended practice and modeling with this strategy as research shows students require frequent opportunities to practice self-regulation to maintain skills over time (Montalvo & Torres, 2008).

In addition, future studies would benefit from providing students direct instruction in use of the SRPF form to ensure that students understand this form of feedback. Research has shown that adults are better able to monitor their own performance when prompted to do so. Conversely, children and adolescents have difficulty using self-monitoring given that it is a complex metacognitive activity that requires directed attention and sophisticated reasoning processes. Research indicates that strategy use involves more than simply knowing or understanding procedures; thus, although students understood they were prompted to use the SRPF form, they may not have fully understood how to apply the information from this form (Schneider, 1985). This may have lessened the strength of the current feedback manipulation of SRPF. Future research can avoid this by providing participants within an SRPF group with direct training in completing the SRPF form, as well as training in applying that self-generated process feedback to make appropriate SRL decisions on the next math problem (Ghatala, 1986; Ghatala, Levin, Pressley, & Goodwin, 1986; Moynahan, 1978).

Because the current study's findings may have been affected by students not considering the feedback to be meaningful or relevant, it would also be important to incorporate checks in student understanding and reception of the feedback either in the form of a pretest or throughout the intervention (Hattie, 2012; Lloyd & Trangmar, 2012).

Implications for School Psychologists

The findings from this dissertation hold implications for the practice of school psychologists and other school personnel. Prior literature indicates that process feedback can positively affect students' academic achievement and engagement in SRL processes (Labuhn et al., 2010). Specifically, research clearly states that students benefit when teachers or parents provide process feedback as this directs the learner's attention to adapting. EXPF can also result in increased achievement and SRL engagement (Geister, Konradt, & Hertel, 2006; Schunk & Pajares, 2002), as well deeper learning and processing of information (Balzer et al., 1989, Hattie & Timperley, 2007). Along a similar vein, SRPF has been linked with similar positive effects on SRL and achievement (Kitsantas & Zimmerman, 2006; Stone, 2000). SRPF has also been attributed potential additional benefits due to the inclusion of self-monitoring and self-recording (Chularut & DeBacker, 2014; Graham, Harris & Reid, 1992; Harrish & Graham, 1992) which can further affect internal self-regulatory development (Chung & Yuen, 2011) and students' ownership (Gagné & Deci, 2005) and integration (Davis, 2000) of the learning process.

The current study was interesting because it contradicted much of this process feedback research. From the author's perspective, the null findings suggest that the context of the EXPF or SRPF manipulations may impact its effect on academic achievement or SRL processes.
Given the literature indicating EXPF and SRPF's positive effects on SRL and academic achievement, the current null findings suggest that school psychologists and other school personnel should pay close attention to the fit between the difficulty level of the task, as well as the complexity of the task and scope of the intervention. In addition, with regard to the implementation of these two empirically-based types of process feedback, (i.e., EXPF and SRPF) school personnel should be mindful of training that students might need to adequately interpret and use this feedback.

In the presence of these null findings, school psychologists should work with other school personnel and instructors to ensure that students are met with adequately challenging and stimulating assignments in order to promote their motivational and self-regulatory processes toward academic engagement (Bandura, 1997; Ramdass & Zimmerman, 2011; Usher & Pajares, 2008). This study provides an example wherein students were faced with an academic task that was too easy for them, as shown by their generally accurate performance throughout the entire MPS session. In the absence of an academic challenge, students did not show any changes in their academic performance or use of SRL strategies during learning. This coincides with literature indicating that self-regulated learning is context-dependent in that it "develops through purposive engagement with the fundamental concepts and structure of subject matter as students wrestle with complex and challenging tasks along the mastery pathway" (Boekaerts & Corno, p. 223, 2005). Therefore, as school practices look to increase student achievement and SRL processes, personnel must individualize curriculum materials to include appropriately challenging materials in order to create an environment with room for students to grow in these areas. This can be accomplished through pre-assessments in which teachers collect baseline data on students' skills. Baseline data can be collected through teacher-devised assessments, standardized tests, and review of previous records or evaluations. Once instructors are armed with this data, they can responsively create tasks that motivate students to strive for greater skill acquisition. It continues to be important to review and assess the level of students' skill acquisition as new units are introduced so as to continually provide students with tasks that are sufficiently difficult to require increased self-regulation. As school staff achieve a balance between task difficulty level and students' ability, this sets the tone for general learning engagement, as well as students' increased SRL engagement and subsequent achievement (Hattie, 2012). Kulhavy and Stock's (1989) model also indicates students present with increased attention to feedback in the context of appropriately challenging tasks. Therefore, selection of the appropriate task for students will affect students' engagement with feedback, the academic task, and SRL processes.

This study's findings also indicate that students may need extended practice opportunities when attempting to learn, and learning strategies, for complex tasks such as MPS. Prior research has supported this premise (Montague et al., 2014; Nietfeld et al., 2006). The short-term intervention used in the current study may be more appropriate for simpler, single-step math skills in which students may be more likely to demonstrate improved math performance through a shorter intervention (Ramdass & Zimmerman, 2008). As the current study and other research shows that shorter interventions may not be as powerful in creating changes in students' SRL engagement (Ramdass & Zimmerman, 2008), school psychologists can work with teachers and administrators to build in a separate component to target SRL improvement when a shorter academic intervention is being utilized.

Finally, the discussion of this study's findings indicated that the null findings may also be linked to the lack of specificity within the EXPF, as well as lack of explicit training in students' use of the SRPF form. School psychologists can be instrumental in serving a consultative role with teachers to implement all types of process feedback with increased specificity as described in the literature (Bangert-Drowns et al., 1991; Merry & Osmond, 2008; Pridemore & Klein, 1995; Shute, 2008; Williams, 1997).

School psychologists can help ensure the quality of the feedback implementation through leading professional development for teachers, instructional assistants, and other staff who have direct instructional interaction with students. Professional development can be an opportunity for school psychologists to educate staff members on empirically based reasoning for implementing these types of process feedback, as well as provide training in how to do this within the classroom. Given the current study, school psychologists should particularly train teachers to provide specific process feedback to students so that the specificity of the feedback can better help students to learn the skills and improve SRL engagement. As the lack of significant findings in this study may have been related to students' potential lack of understanding of the SRPF form, school psychologists' consultative role should also include sharing the importance of student training when using SRPF. School psychologists can assist teachers in development of SRPF forms that are specifically tailored to the academic tasks in order to create empirically-based SRPF forms. When students are properly trained, SRPF can be used to facilitate the specificity of process feedback as students are guided to self-generate this vital information (Cleary et al., 2006).

In light of the lack of significant findings for the use of SRPF within the current study methodology, school psychologists can also support powerful implementation of SRPF by engaging in direct service to support students' training in use of SRPF. This may occur through integration into individual or group school-based counseling sessions, as well as more informal check-ins with students on case management caseloads. This training can be empowering for students in helping to learn how to self-monitor, and fully understand the process and ownership of their own learning. This support would also benefit teachers as school psychologists ensure that these students receive reinforcement on how to use this feedback through SRPF forms that may be used within the classroom or specific content area. Work on this in school-based counseling or other related services such as speech and language counseling can help the student generalize the skill of using the SRPF form in other settings, which will further reinforce the students' skill set in using the SRPF materials.

This study also has implications for school psychologists' Individual Educational Plan (IEP) development. As the current study supports the literature stating that process feedback may be most effective when clear and specific, school psychologists may choose to include specific process feedback instructions in the lists of accommodations provided to a student within the IEP document. These accommodations might include specific process feedback in order to ensure that students receive feedback that is beneficial to both SRL processes and academic performance across educational contexts. IEP development may also include that students should be provided training in use and understanding of the type of feedback when new types of feedback are introduced, such as SRPF, in order to ensure the success of that type of feedback. The IEP can also include instruction that the staff working with the classified student receive training in how to appropriately implement process feedback.

These findings are also conducive to school psychologists' impact with the administrative organization. School psychologists often work closely with the administrative team to ensure that both general education and special education students are learning to the best of their ability with differentiated instruction. This training can be used to ensure that classes and curriculum are organized so that process feedback is appropriately integrated into the classroom to best facilitate learning. Therefore, school psychologists can collaborate with administrators to inform them about the importance of being mindful of parameters such as complexity of the task, difficulty level of the task, training in SRPF, and specificity of process feedback, as administrators evaluate and assist teachers in their instructional practices. School psychologists may also broaden their reach through parent training that educates parents on the importance of process feedback and parameters of this feedback. It would be important for parents to understand that students must be appropriately challenged to facilitate their development of these important SRL processes, because without an environment of appropriately challenging academic tasks, students are not required to evaluate, reflect, and adapt their SRL processes. Providing this education to parents will be useful in getting parents on board with school expectations for students to be increasingly challenged with the goal of creating opportunities for promoting SRL engagement and subsequent academic growth.

Conclusion

The results from the current dissertation were disappointing in that they did not provide support for the a priori predictions. This study also did not reveal significant adaptive shifts in

SRL processes within feedback groups. However because all three groups reported generally high self-efficacy and MPS performance, there was no need for them to regulate or adapt strategy use. Through the continued research and refinement of aspects of this study, future research can be useful in exploring further the relationship between types of process feedback and high school students' engagement in SRL processes and mathematical achievement.

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Appendix A. Literature Review

Introduction

For the past twenty years, some researchers have identified the need for research to examine feedback dynamically and within more discrete learning situations in order to thoroughly analyze feedback's continuous roles in learning (Butler & Winne, 1995). As more information is gained on the parameters of the effective delivery of feedback, it has been found that two of the most successful types of feedback for enhancing performance include feedback directed on process of learning and feedback encouraging the self-regulation of students' learning such as through self-generating feedback (Hattie & Timperley, 2007). As SRL research has shown that self-regulatory processes also benefit students' learning and performance, researchers have begun to explore how to foster SRL within academic settings through manipulations of different types of feedback (Cleary et al., 2015; DiBenedetto & Zimmerman, 2010; Schunk & Swartz, 1993). This study responds to this trend of exploring the relationship between feedback and SRL processes by studying feedback within the context of a self-regulation perspective in order to understand fully the impact of feedback on the cognitive and motivational SRL processes and learning performance (Ashford & Tsui, 1991; Butler & Winne, 1995).

Overview of the Chapter

This chapter will be devoted to the explanation of key constructs and concepts related to this dissertation. First, the author will define feedback and describe the two types of feedback that will be studied in this project. As the two types of process feedback are a central focus in this study, the author will provide background literature information regarding the implementation of these two types of feedback, particularly within academic contexts. Next, a definition of SRL and a description of a comprehensive model of SRL based on social cognitive theory will be presented along with a description and explanation of how the following SRL constructs have been shown to have important roles in academic performance: self-efficacy, goal-setting, strategic planning, and strategy use. The characteristics and features of the primary tool of measurement of the study, SRL microanalysis, will be discussed in relation to these constructs and the chosen academic task of MPS.

The author will also explore the connection between the general constructs of feedback, SRL, SRL microanalysis, in relation to the engagement in mathematics, and specifically MPS. The author will underscore the importance of problem-solving competence for students' academic future in mathematics and holistic education, and explain the importance of providing direct strategy instruction in conjunction with feedback to facilitate the process of learning and SRL processes utilized in performance. Overall, the purpose of this chapter is to provide separate and integrated information on how the literature on feedback and SRL will assist in understanding the mechanics of this study within the historical context and current literature on studying how feedback impacts shifts in students' SRL processes and MPS performance.

Feedback Defined

Feedback represents a new instructional method of bridging the gap of learning. Kulhavy (1977,) argues that feedback can give information an instructional purpose by offering information that is directly linked to the task and bridging a gap between what is understood and what is aspired to understand. Feedback occurs within the learning context as secondary to initial instruction and is used with the purpose of providing new information to supplement and specifically address earlier learning with the purpose of enhancing future learning and performance (Kulhavy, 1977).

Some parameters for the successful impact of feedback on performance include that the student is capable of receiving the feedback, understanding the feedback, monitoring affective processes, and engaging in self-directed learning behavior needed to act on that behavior (Price, Handley, Millar, & O'Donovan, 2010). Additional areas of interest include identifying the characteristics of effective feedback, such as whether it should be immediate or delayed, students' role in proactively generating their own feedback, or the types of feedback that are most effective (Kulhavy, 1977; Mory, 2003; Nicol & Macfarlane-Dick, 2006; Orrell, 2006; Hattie, 1999). Within feedback, there must be a clear distinction between giving feedback about a specific product versus executing judgments on the learner as a person. This has implications for using vocabulary that clearly evaluates the learning processes rather than narrowly emphasizing the learner's abilities (Boud, 1995). This study presented a structured way to use what prior research has demonstrated about effective parameters of feedback such as the aforementioned characteristics, and build upon that information by analyzing the effects of three types of feedback on performance and affective, regulatory processes.

Though feedback has been viewed as a potential instructional method of bridging a learning gap since the early 1900s, the confusion regarding three classes of feedback definitions have continued to prevail in the current literature since the early 1900 definitions (Mory, 2003). Kulhavy and Wager (1993) summarize three historical conceptualizations of feedback as feedback functioning as a motivator to increase response rate and/or accuracy, a reinforcing message for correct responses, and as error correction information. Research on feedback has been primarily conducted from the information processing perspective for the past three decades. However, the literature remains inconclusive regarding the best practice for feedback delivery (Mory, 2003). Past research indicates that feedback's primary role is to identify errors and facilitate learners' adoption of correct alternatives (e.g., Anderson, Kulhavy, & Andre, 1972; Birenbaum & Tatsuoka, 1987; Kulhavy, 1977). Studies have shown that learners who receive feedback are more likely to correct their errors than learners who do not. Phye and Bender (1989) support this principle in that when feedback was not available people most frequently made the same error multiple times, whereas this pattern did not occur in feedback conditions. In addition, feedback has been shown to facilitate strategy generation relative to conditions without feedback (Alibali, 1999). Overall, literature suggests feedback assists learners in rejecting erroneous thoughts and engage in behaviors to search for improved alternatives (Fyfe et al., 2012).

Despite the variety in the feedback research, researchers largely agree that when learners attend to externally provided feedback their learning is more effective (Butler & Winne, 1995). In addition, research shows that the delivery of feedback for instructional purposes is particularly helpful for students with low prior knowledge (Krause, Stark, & Mandl, 2009). More information is needed to understand how feedback can best be used to facilitate successful academic learning. In order to further understand the mechanisms of feedback, it is necessary to study feedback in educational activities in a way that is mindful of the temporal nature of feedback and sensitive to feedback following smaller, more discrete tasks (Butler & Winne, 1995). This study built upon this information and adds further specificity by studying the differences between two types of process feedback and outcome feedback to discern which type of feedback is most helpful for students within mathematics.

General feedback practice. There are a variety of instructional practices for feedback that instructors or teachers can use to enhance SRL and achievement. Feedback can be provided in written feedback or orally and can be used to help students analyze errors. Instructors should provide frequent opportunities for reflection and practice by giving frequent feedback. For students who struggle in school, feedback tends to work best when it occurs frequently and students are given the chance to practice making adaptations thus practice opportunities should follow the administration of feedback (Cleary, 2011).

Through a synthesis of previous meta-analyses studying the impact of feedback in classrooms, Hattie (1999) demonstrated that feedback has a strong impact on achievement. Specifically, feedback resulted with an effect size of 0.79, which was in the top 5 – 10 highest influences on achievement with direct instruction (0.93), reciprocal teaching (0.86), and students' prior cognitive ability (0.71). Hattie (1999) also considered and demonstrated the strong effect sizes of other influences such as homework (0.41) and reducing class size (0.12), however, overall this review of literature emphasized the power of feedback on achievement. Additionally, Hattie's (1999) synthesis highlighted how different types of feedback are more powerful than others. Studies demonstrating highest effect sizes provided students with information feedback regarding a task and how to do it more effectively. Specifically, feedback relating to goals was found to be one of the most effective forms of feedback for enhancing achievement (Hattie, 1999). In comparison, praise, rewards, and punishment resulted in lower effect sizes (Hattie, 1999). Dweck (2008) provides a similar finding in that praise for process (i.e., praise on a student's effort or strategy) results in more adaptive impacts in that students tend to seek and thrive on challenges whereas students receiving praise for intelligence or result may be more likely to avoid more challenging tasks so as to continue looking intelligent. Overall, effective feedback will help to create a shift in student thinking so that a learner focuses on how well one performed as well as the reasons why that performance outcome occurred (Hattie & Timperley, 2007).

Not only does research state that feedback promotes achievement, but Kluger and DeNisi's (1996) systematic meta-analysis suggest that feedback has a more powerful effect when it includes information on correct rather than incorrect responses and when it builds from changes from previous attempts. Feedback also demonstrated the most impact when paired with specific and challenging goals and low task complexity. Praise, rewards and punishment have resulted in lower effect sizes and differ from feedback because these constructs contain scarce learning-related information (Deci, Koestner, and Ryan, 1999; Hattie, 1999; Kluger and DeNisi, 1996).

Butler and Winne (1995) indicate that studying feedback with relation to global tasks leaves a gap in the literature and that feedback instead should be studied dynamically and for more discrete learning situations. Butler and Winne further assert that feedback should be studied within the context of a self-regulation perspective in order to fully understand the links between cognitive and motivational engagement with feedback and the impact on learning that occurs when self-regulatory processes are paired with feedback (Ashford & Tsui, 1991; Butler & Winne, 1995).

There is a need for research to systematically study the impact of multiple types of feedback, such as EXPF, SRPF and outcome feedback, to provide information on which feedback not only provides greater increases in performance but also greater use of SRL processes (Cleary et al., 2015).

Two types of feedback: EXPF and SRPF.

This dissertation was designed to add an important layer of information to the field of research on feedback and SRL by measuring the effects of three types of feedback (i.e., EXPF, SRPF, and outcome feedback) on student achievement and SRL. Previous studies have examined the effect of one type of feedback on shifts in SRL processes in an academic context (Cleary et al., 2015). This section reviews information on two constructs, SRL and feedback, that have been shown to be two of the most important influences on student academic learning (Corno & Mandinach, 1983; Hattie & Timperley, 2007; Pintrich & De Groot, 1990). Though feedback has been described as the most powerful single influence on student learning and achievement (Gibbs and Simpson, 2004), feedback may not be effectively used or provided to all students (Higgins, Hartley, & Skelton, 2001). Therefore, students need to develop the ability to use feedback (Sadler, 1989) and research needs to continue to assess and specify effective ways to implement feedback.

EXPF. Hattie and Timperley (2007) present a model of feedback that describes how feedback can operate at different levels with negative or positive connotations for motivation with a task (Dweck, 2000; Mueller & Dweck, 1998). Depending on the level at which feedback operates (i.e., self level, task level, process level, and self-regulatory level) will determine whether that type of feedback enhances or inhibits cyclical processes of regulation during an academic task (Hattie & Timperley, 2007).

When provided effectively, EXPF focuses on strategy use and self-regulation processes. This information is designed to highlight the discrepancy between perceived and actual performance by directing attention to essential strategic requirements of a task or the behaviors or processes that need to be adapted to correct mistakes (Sandars & Cleary, 2011). EXPF has been described as the most relevant type of external feedback for effective or enhancing self-regulation processes, though it is not as common as other types of feedback (Sandars & Cleary, 2011).

Research has shown that remedial readers benefit from explicit EXPF as they attempt to mastery a reading comprehension strategy (Schunk & Rice, 1991). In this study, fifth grade students with low comprehension skills were assigned to a product goal, process goal, or process goal plus EXPF condition. Though Schunk and Rice (1991) called the feedback progress feedback, it refers to the same definition used in this study for EXPF. Accordingly, students were told to try to answer questions about what they read (i.e., product-goal), advised to try to learn how to use the steps in the strategy instruction to answer questions about what they read (i.e., process-goal children), and provided a process-goal and also periodically given verbal feedback that linked their improved performance to strategy use (e.g., “You got it right because you followed the steps in order.”). Process goal plus EXPF students evidenced higher self-efficacy and reading comprehension in comparison to process- and product- goal only learners. Students receiving EXPF used it to engage in greater evaluation of their strategies as they worked to attain a process goal.

Schunk and Rice (1992) implemented strategy-value feedback that was similar to the aforementioned progress or EXPF. Poor readers receiving strategy-value feedback (i.e., EXPF) or strategy-modification instruction demonstrated higher self-efficacy, reading comprehension, strategy use, and transfer of the strategy to a new comprehension task in comparison to students receiving the instruction without the strategy modeling. Schunk and Rice (1999) extended this line of research by randomly assigning 33 elementary school students to one of three experimental conditions: strategy instruction, strategy value feedback (i.e., EXPF), and instructional control. The study provided 35-minute instructional sessions over 15 consecutive school days during which students worked on a packet of materials. In the strategy instruction groups, students received a modeled strategy session. Students who received strategy value feedback (i.e., EXPF) received feedback linking their successes at answering comprehension questions with their proper application of the strategy; the teacher delivered this feedback three or four times during each instructional session after a child properly performed a step or answered a question correctly. Students assigned to the instructional control condition received the same amount of instruction without the comprehension strategy or feedback. Posttest results showed that the students receiving the EXPF resulted in the highest self-efficacy, skill, and maintenance of strategy use. This feedback served to teach students that the strategy is effective, they were making progress in learning, and they are capable of continuing to improve their skills and their successful application of the strategy validated these beliefs. Students receiving strategy instruction did not differ from control group students on self-efficacy or comprehension performance (Schunk & Rice, 1999).

Schunk and Rice (1993) implemented an experiment wherein half of the children in different conditions intermittently received EXPF that linked strategy use with improved performance. In the EXPF condition, students received information about their use of strategies rather than their end product of the task; one finding of the study supported the combination of providing strategy instruction plus fading with strategy-value feedback that informed students that the strategy is effective, they are making progress in learning, and they are capable of improving their skills. Students receiving this combination of strategy-use feedback, EXPF feedback, along with fading of a strategy instruction, produced the highest self-reported strategy use and greatest skill. Schunk and Swartz (1993a, 1993b) explored the effects of EXPF on the self-efficacy and writing achievement of children. Schunk and Swartz (1993a, 1993b) demonstrated positive effects of EXPF when teachers used the feedback to link students' use of the strategy's steps with student's improved writing performance. Average-ability and gifted elementary students received instruction on writing paragraphs over 20 sessions and were taught a five-step strategy: choose a topic to write about; write down ideas about the topic; pick the main idea; plan the paragraph; write down the main idea and the other sentences. After all children were instructed in the writing strategy students were given one of three goals (a process goal of learning the strategy to write paragraphs, a product goal to write paragraphs, or a general goal to work productively). Half of the process goal children also intermittently received EXPF on how they were progressing in the strategy learning. Results demonstrated that the group of children with the process goal and the EXPF had the greatest improvement of achievement outcomes, as well as maintenance and generalization. Specifically, across average and gifted students, process-goal plus EXPF students outperformed product- and general-goal students on self-efficacy and writing achievement, evaluated the effectiveness of the strategy the highest, and demonstrated the greatest strategy use. Students receiving a process goal and EXPF maintained skills after six weeks and generalized these skills to writing other types of paragraphs.

Zimmerman and Kitsantas (2002) explored the effect of modeling and EXPF on college students' self-regulatory writing revision skill acquisition. Six conditions were utilized and intervention involved presenting students with a mastery model that demonstrated the revision strategy perfectly, a coping model who made and corrected errors with gradual improvement in performance, and no exposure to a model. Partial students in each condition received feedback during the practice session that followed the modeling in which students received EXPF about the strategy steps they performed correctly. A coping model led to greater increases in writing self-efficacy and skill, and the mastery model improved outcomes more than students viewing no model; importantly, the addition of EXPF led to gains in self-efficacy and skill in writing revision.

In sum, experimental studies have demonstrated EXPF to have positive effects on students' skill acquisition and self-regulatory processes when provided in the context of an academic task. In addition, Earley, Northcraft, Lee and Lituchy (1990) and Balzer, Doherty and O'Connor (1989) assert that EXPF is more powerful in improving task performance than is corrective, or outcome, feedback. When literature suggests that EXPF is more effective in improving task performance, often the rationale states that EXPF focuses the learner more directly on task strategies and facilitates a deeper learning than occurs with outcome feedback (Hattie & Timperley, 2007). Despite the literature's assertion of the positive impact of EXPF on performance, research remains inconclusive with regard to what type of feedback is most effective for improving regulatory processes.

SRPF. Hattie and Timperley (2007) indicate that feedback can be self-generated or it can be provided from social sources. SRPF enables learners to generate informative internal feedback them helps them effectively adapt behavior for learning (Sandars & Cleary, 2011). SRPF is designed to help promote engagement in forethought, performance, and reflection regulatory processes. SRPF has been found to increase task interest and certain self-regulatory processes such as self-efficacy for performing tasks, as well as direct attention on how to self-manage or regulate learning on specific tasks (Hattie & Timperley, 2007). According to Butler and Winne (1995), who label SRPF as self-monitoring, SRPF is central to self-regulated learning as students self-monitor when they reflect on various aspects of their performances and generate internal feedback regarding progress. Engaging in self-monitoring helps students determine whether their target behavior has or has not occurred and then prompts them to record this information. In a sense, self-monitoring can be broken down into two components: self-assessment and self-recording (Chularut and DeBacker, 2014; O'Leary & Dubey, 1979). Though learners can involve themselves in self-monitoring wherein they make assessments about their work, this process works best when combined with self- (Graham, Harris, & Reid, 1992; Harris & Graham, 1992). Research calls for developing various ways of giving students the opportunity to practice self-assessment activities such as SRPF in order to help learners engage with the criteria which distinguish acceptable from unacceptable performance and to actively encourage SRPF (Boud, 1995).

In short, SRPF refers to information that is produced by the individual learner and focuses on the learner's process of engaging in a task rather than outcomes or products. Teaching students to generate SRPF will typically involve having students record their study strategies or behaviors (Nietfeld et al., 2006).

Schunk and Rice (1993) described the SRPF process by including a methodology in which teachers required students to verbalize the strategy's steps as they performed them. With practice throughout the study, some children were asked to fade their overt verbalizations to silent inner speech that was called a fading process and meant to internalize the students' self-generated feedback to promote strategy internalization. When students were provided EXPF about strategy usefulness and also prompted to give themselves SRPF via self-statements about the strategies, students demonstrated higher comprehension compared to when students only received EXPF. Students receiving EXPF and SRPF also exhibited higher levels of self-regulatory skill development (Schunk & Rice, 1993). Schunk and Rice's (1993) study supports the research that states that students need to internalize strategies in order to help enhance self-regulation processes, which can be done through strategy verbalization or guiding students in self-monitoring processes to engage in SRPF.

Zimmerman and Kitsantas (1999) investigated the development of high-school students' self-regulatory writing revision skills through manipulation of goal-setting and SRPF. Students observed a modeled demonstration of a three-step writing revision strategy and were assigned to a condition to practice the strategy. Students were either provided outcome-goals to rewrite the sentences with minimal words, a process-goal to concentrate on using key steps in the strategy, or a shifting-goal to first focus on the steps and then the amount of words used. Some of the students in each condition were told to engage in SRPF by recording the number of strategy steps done correctly during the task or to engage in outcome feedback by recording the number of words in the steps. There was also a condition of students who received the same modeling instruction without goals or self-recording input. Results indicated that students who engaged in SRPF demonstrated increased writing skill and self-efficacy.

It is important to note that self-monitoring is closely related to and can overlap with external feedback. Teachers can provide direct feedback and can structure self-monitoring activities to help students gather the same types of information (Cleary, 2011). Self-monitoring is also critical to becoming a strategic learner as the process of self-monitoring encompasses strategies, such as monitoring one's progress towards learning goals, setting learning goals, planning ahead, independently motivating oneself to meet a goal, focusing attention on the task, and using learning strategies to facilitate one's understanding of the material (Zimmerman, 2004). Therefore, feedback that is generated through self-monitoring can have the additional benefit of promoting development of other SRL processes. SRPF can be encouraged or facilitated by guiding students in keeping a record of various types of information, such as the amount of attempts on a learning task, strategies used, and amount of time spent working on the task. This self-monitoring process can be used before, during, or after the task to reflect and visualize one's progress and make changes as needed.

Outcome Feedback. Simple outcome feedback is the most common type of feedback. It focuses on outcomes and performance. This type of feedback will describe the correctness of responses (Hattie & Timperley, 2007; Butler & Winne, 1995). Unfortunately, and as noted by Butler and Winne (1995), corrective or outcome feedback provides minimal information about the task other than whether the outcome is correct; thus, it tends to give minimal guidance about how to adapt or change strategy use. Conversely, Hattie and Timperley (2007) suggest that feedback regarding how well a task is being accomplished, or knowledge of results, is a foundation for effectively building processing and self-regulation. A synthesis of reviews indicates that outcome feedback may be most helpful when it is paired with process feedback to be used to assist the rejection of erroneous hypotheses and to prompt or cue information about the task (Hattie & Timperley, 2007).

Outcome feedback provides information about how well a task is being accomplished or the level of correctness, such as by providing the accurate solution, or stating that the student needs to do more or less of something, such as, "you did not show your work." Task feedback provides the benchmark for students to evaluate; thus, the more clear and specific the outcome feedback, the more specifically one can analyze performance (Hattie & Timperley, 2007). Though outcome feedback remains important for future learning, it does not direct students' attention to the strategies as occurs in different ways during EXPF and SRPF; without any feedback explicitly attenuating students to strategies, students will not self-direct attention to strategies. Students' academic performance is expected to have a degree of improvement when provided only outcome feedback, however, greater impact on performance and SRL is found when outcome feedback is paired with a type of process feedback (Hattie & Timperley, 2007).

Definition of Self-Regulated Learning

Due to the emerging interest in SRL processes in academic contexts as well as the potentially powerful effects of feedback on how students approach learning, this study sought to evaluate the impact of different types of feedback (i.e., EXPF, SRPF and outcome feedback) on shifts in students' SRL processes and subsequent mathematics achievement. As students enter higher grade levels, they are often met with more intensive or comprehensive tasks that require them to become more self-directed and adapt to different learning environments (Schmitz & Perels, 2011; Zimmerman, 2002). It is important to assess student SRL processes because these processes often predict adaptive classroom and academic outcomes (Graham & Harris, 2005). This study was aligned with the need to assess and implement feedback within an SRL framework with the goal of gaining information in how to facilitate students' proactive, regulated role in generating and using feedback (Nicol & Macfarlane‐Dick, 2006). It was hypothesized that feedback would be more efficient in correcting knowledge and improving performance when provided with an awareness and assessment of self-regulatory subprocesses that surround the discrete task (Culotta, Kristjansson, McCallum, & Viola, 2006; Higgins et al., 2001).

This study focused on the social cognitive theory (SCT) of self-regulation as it accounts for the "separate but interdependent contributions of personal, behavioral, and environmental influences" on learning (Zimmerman, & Schunk, p. 17, 2001). SCT asserts that an individual's strength of will and intentions will not be sufficient for self-directing and managing one's own behaviors. Expanding upon Bandura's premise that humans have the ability to exert active control and influence on behaviors through regulatory subprocesses such as self-observation and self-judgments, Zimmerman (p. 14, 2000) defined self-regulation as: “self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals.”

SRL refers to the regulation of stress, moods, thoughts, attention, and impulses such as aggression, sexual arousal, and emotions. In the conceptual model of the cycle in which SRL occurs, individuals utilize a variety of sub-processes to manipulate and manage their cognitions, motivation, and behavior while engaged with a task (Bandura, 1986; Zimmerman, 2000; Callan, 2014). There are several sub-processes within SRL that have a strong research base such as goal-setting, strategic planning, strategy use, and self-efficacy. With regard to metacognitive processes, self-regulated learners are more likely to plan, set goals, organize, and self-monitor their learning at various points of acquisition, and self-efficacy is a motivational process that would also reflect a higher level approach to learning (Corno, 1986, 1989; Ghatala, 1986; Pressley, Borkowski, & Schneider, 1987).

Zimmerman’s (2000) cyclical model of SRL. The theory behind the SRL cycle is that the SRL subprocesses occur in a cyclical loop with three interdependent phases (See Figure 3). The forethought phase occurs before the initiation of a task and involves motivational and cognitive beliefs useful to engage in before a task to enhance performance. The performance control phase occurs during the performance or learning, in which the individual uses strategies and behaviors to monitor his or her performance. The third phase, self-reflection phase, is where the individual systematically engages in processes such as self-evaluation to learn from the task and optimize future learning. The cycle is complete when self-reflection processes impact the next cycle, which can be observed through impact in the forethought phase sub-processes (Zimmerman, 2000). This study will observe a complete cycle in addition to exploring the impact of feedback on the next SRL cycle sub-processes in the MPS task.

This study will focus on several sub-processes within SRL that have a strong research base, such as self-efficacy, goal-setting, strategic planning, and strategy use, with positive implications for academic learning (Bandura, 1986; Zimmerman, 2000; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Joo, Bong, & Choi, 2000; Zimmerman & Kitsantas, 2007; Zimmerman, 2008).

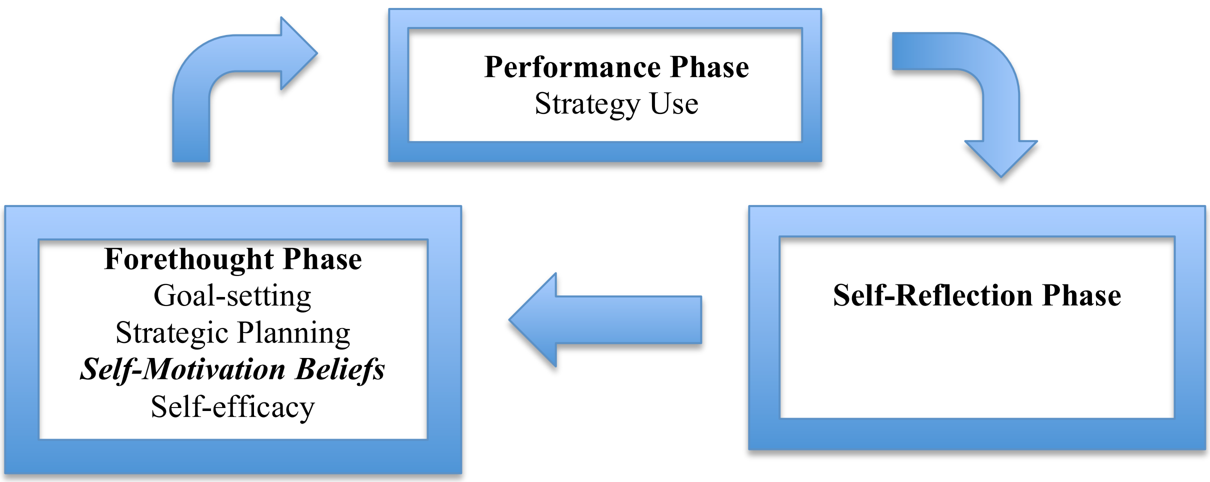

Figure 3. Cyclical Phases and Subprocesses of Self-regulation Specific to This Study. Information garnered from Cleary and Zimmerman (2001) and Cleary et al. (2015).

Self-efficacy. SCT highlights self-efficacy as a key process in human learning. Self-efficacy refers to the beliefs that an individual has about his or her capability to succeed in his or her endeavor, and this belief has been shown to be a crucial force in the subsequent individual's successes or failures in the relevant endeavors (Pajares & Schunk, 2006). A person's self-efficacy is a major source of motivation; people will be more intentional in their actions if they have higher levels of self-efficacy. Such a student will have greater agency and active engagement in learning. Affective processes, such as self-efficacy, enhance use of self-regulation strategies; thus a student's self-regulation processes (self-control and self-evaluation) paired with high perceived capability (self-efficacy) can transform how learning occurs. Self-efficacy occurs during the SRL forethought phase as the individual systematically assesses his or her own self-efficacy before engaging in a task in order to optimize performance or learning.

Social cognitive theorists have labeled self-efficacy as a key factor affecting self-regulated learning (Zimmerman, 1989) as students with high self-efficacy have been shown to set more ambitious goals and engage in more planning about the types of strategies they will use to accomplish tasks (Pajares, 2008; Zimmerman & Cleary, 2009). Self-efficacy is measured by assessing people's confidence in their ability to perform specific behaviors relative to a standard level of achievement (Bandura, 2006). These beliefs do not refer to an overall or global measure. Personal self-efficacy beliefs can vary over different tasks and skills so that a person can have differentiated self-beliefs that correspond to distinct contexts and tasks of functioning, and thus result in various levels of self-efficacy (Bandura, 2006). Self-efficacy beliefs have been noted to impact how well individuals motivate themselves in the face of adversities and how individuals self-regulate behaviors and thoughts. Therefore, a combination of student's self-efficacy beliefs and reporting of how the student is actually performing can help estimate what the student will do with the knowledge and skills they possess.

Self-efficacy is as an important factor in feedback situations as it has been described as a parameter of successful feedback in which feedback is determined effective to the extent that it directs information to enhance self-efficacy due to the connection between enhanced self-efficacy and subsequent self-regulation, attention to the task, and increased effort for the task (Kluger & DeNisi, 1996). It is important to study the impact of types of feedback on self-efficacy because when students develop positive concepts of self-efficacy about learning a specific task this leads to further learning as students with heightened self-efficacy may be more willing to engage in increasingly challenging tasks (Hattie & Timperley, 2007).

Research has demonstrated relations between self-efficacy and students' academic achievement. Students with strong self-efficacy have been shown to exert greater effort and persevere longer in trying to accomplish their goals (Bandura, 1997; Eccles & Wigfield, 2002). Pajares and Graham (1999) demonstrated a predictive nature for self-efficacy in that students' task-specific self-efficacy has been shown to predict middle school students' mathematics performance. Similarly, Pajares and Miller (1994) revealed that math self-efficacy was more predictive of problem-solving than other motivational variables. In the work by Pajares and Graham (1999), gifted students were also shown to have more accurate and less overconfident self-efficacy beliefs in comparison to regular education students. Increased self-efficacy can assist learners' ability to predict, regulate and revise judgments; students' self-efficacy is impacted as students' self-awareness increases with regard to personal strengths and weaknesses in performance. Conversely, a student with poor self-efficacy usually is impacted by low motivation and accordingly may devalue tasks (Cleary & Chen, 2009; Eccles & Wigfield, 2002; Schunk, 1991). Therefore, self-efficacy has implications and consequences for both motivation such as persistence and self-regulated behaviors such as strategic involvement that can impact academic achievement (Cleary & Zimmerman, 2004; Schunk, 1984). This study's inclusion of a measure of self-efficacy responded to calls in past research for self-efficacy to be included in the pursuit of understanding how a range of motivational beliefs impact students' regulatory behaviors and mathematics achievement (Cleary & Chen, 2009) in response to more elaborate feedback variations (Kitsantas et al., 2000).

Goal-setting. During the SRL forethought phase, individuals systematically engage in setting goals in order to optimize performance or learning. Goal-setting is a particularly important component of self-regulated learning (Pintrich, 2000; Zimmerman, 2000, 2008) as students engage in cognitive activities wherein goals can provide standards against which people compare their present performances (Bandura, 1986). As goals function as criteria for a learner to judge how he or she is doing in an achievement situation, goals also help the learner make decisions about how to continue to regulate their activity or possible necessary changes in behavior (Wigfield, Klauda, & Cambria, 2011). As goal-setting occurs in the initial phases of SRL, it also has motivational implications that motivation for learning tasks has been linked closely to the initiation and sustenance of goal-directed behavior (Cleary, 2011). Goal-setting behavior has also been linked to highly self-regulated learners as they proactively set goals and create plans for attaining those goals (Cleary & Zimmerman, 2004).

Effective goal-setting depends on specificity, proximity, and level of difficulty of the desired goal and appropriate consideration of these parameters is useful before goals can be defined and accomplished (Schunk, 1990). Goals stating specific performance standards are more likely to enhance behavior in comparison to general goals, such as “do your best.” Further, challenging but attainable goals increase motivation and learning significantly more than goals that may be perceived as overly difficult or easy (Schunk, 1991).

In addition, goal-setting can interact with other self-regulatory processes, such as self-efficacy, in that when students adopt a goal and achieve it they may experience greater self-efficacy, which can have positive effects on motivation and subsequent behavior. There is research supporting the process of helping learners set goals for themselves as findings indicate people are more likely to be motivated to work toward goals when they set those goals for themselves as opposed to goals that were imposed upon them (Schunk, 1985). Importantly, goals are beneficial to the extent they are achievable as the continual failure to achieve a goal can result in excessive stress or depression, therefore it is important to remain cognizant of specificity, proximity, and level of difficulty when assisting a learner develop their goals (Bandura, 1986), and once a goal is attained other SRL behaviors can be used in completing that goal. In their review of relevant research of SRL microanalysis, Cleary, Callan, and Zimmerman (2012), illustrate that goal-setting can be measured using open-ended questions in order to examine the types of goals individuals set prior to task engagement. Goal-setting questions are presented immediately before participant engages in the learning task. Also, as researchers have conducted pilot testing to develop and refine microanalytic coding schemes, a review of prior research and literature shows various properties of goal-setting to be important such as indicating that the purpose or focus of the goal is important in that process goals are more powerful than outcome goals and specificity of goal is better than setting ambiguous benchmarks (Cleary et al., 2012).

Research also suggests that the types of goals that learners choose corresponds with motivation, task persistence, and performance. Further, various types of feedback can impact types of goals students set. For example, when students receive feedback regarding effort they have been shown to choose a mastery goal (i.e., involving an activity that was challenging) and when students receive feedback discussing their intelligence they have been shown to respond with a performance goal (i.e., an easy task so as to avoid the risk of embarrassment) (Mueller & Dweck, 1998). Erez (1977) argued that feedback is a necessary and complimentary component toward the effective impact of goal-setting on performance. Within a sample of 86 undergraduate students, Erez (1977) randomly assigned students to an experimental condition that received outcome feedback on performance and a control condition receiving no feedback on performance. Results indicated that students receiving feedback demonstrated a significantly higher relationship between goals and performance in contrast to students who did not receive feedback. Therefore, it is important to assess the type of goal chosen because of implications for strategic performance.

Strategic planning. Another important forethought phase process is strategic planning. The process of strategic planning involves the extent to which a learner chooses strategies that will best address the specific learning challenge. Strategic planning is an SRL process that occurs during the SRL forethought phase as the individual systematically plans the strategies they will use for the task prior to engaging in a task with the aim of optimizing performance or learning.

SRL theorists indicate that self-regulated learners plan, organize, self-instruct, self-monitor, and self-evaluate at various stages during the learning process. In this perspective effective learners engage in various SRL processes such as planning their strategic behavior; the process of planning future strategic actions can help learners understand the relationship between their thoughts and strategic action, which can enhance perceptions of self-control or self-efficacy, and help create positive motivations in future self-regulated learning (Zimmerman, 1986). Planning activities can include the process of setting goals or not. SRL planning activities might include skimming a text before reading, generating questions before reading a text, connecting the information to prior learning, or doing a task analysis of the problem. A strategic plan includes activities that help the learner to plan their use of cognitive strategies. This process also seems to activate relevant aspects of prior knowledge and therefore facilitates the organization and comprehension of material in order to enhance performance. Learners who report using these types of strategic planning activities appear to perform better on a variety of academic tasks in comparison to students who do not plan their strategies (McKeachie, Pintrich, & Lin, 1985; Pressley, 1986). Strategic planning can help students self-regulate their approach to learning before engaging in the learning task. Goal-setting and strategic planning have been described as complementary self-regulatory processes in that planning can assist learners in establishing strategic goals. Strategic planning has earned a place of value in students' learning process because teaching students to approach academic tasks with a strategic plan has been shown to be a worthwhile method for promoting self-regulation and learning (Schneid, 1993). Therefore, this study sought to assess the effects of process and SRPF on changes in high school students' strategic plans over multiple iterations of MPS problems.

Strategy use. Strategy use is an SRL process that occurs during the performance control phase. In this phase, the individual engages in the practice of the task and uses strategies and behaviors to monitor his or her performance and make adjustments to his or her plan of engaging in the task. This SRL subprocess can involve a variety of cognitive strategies, such as rehearsal, organization, re-reading, and elaboration of information that are all applicable to a range of academic tasks (Azevedo, Witherspoon, Chauncey, Burkett, & Fike, 2009) and the self-regulated learner selects and adapts cognitive strategies appropriate to the current task during this phase in the SRL cyclical model (Pintrich & Zusho, 2002).

Strategy use is a broad term for controlled and consciously applied procedural knowledge as opposed to an automatic performance of skills (Veenman, 2011). Researchers have found that students' strategy use is related to academic achievement. Some studies have explained this positive relationship by indicating that motivation may indirectly be connected to adolescents' academic achievement because it promoting students' cognitive strategy use which then fosters academic performance (Metallidou & Vlachou, 2007; Pintrich & de Groot, 1990; Wolters & Pintrich, 1998). Zimmerman and Martinez-Pons (1990) demonstrated that gifted students displayed significantly higher strategy use than regular students, along with higher verbal and mathematical efficacy; these findings suggest that students' perceptions of both verbal and mathematical efficacy were related to students' use of self-regulated strategies. In investigating the effects of sources of strategy information on children's acquisition and transfer of academic outcomes and strategy use, Schunk and Rice (1999) found that students receiving process feedback exhibited maintenance of strategy use that was linked to increased skill. Similarly, Schunk and Swartz (1993) demonstrated that students receiving process feedback reported greater strategy use in writing than students receiving outcome feedback on posttest measures and maintenance tests. Results also supported the finding that increased strategy use also enhances self-efficacy and achievement (Schunk & Swartz, 1993).

Measurement of SRL: SRL microanalysis

SRL microanalysis is a contextualized, structured interview measure requiring the administration of context-specific SRL questions at precise temporal points during the execution of a task (Callan, 2014). SRL microanalytic questions are administered individually to the student during the forethought (before the student initiates the task), performance control (while the student completes the task), and self-reflection phase (after the student has completed the task) in order to gain information about regulatory processes occurring at each phase. Therefore, the task must be defined with a specific beginning and end in order to use this framework. Zimmerman (2000) structures SRL with three cyclical phases (forethought, performance, and self-reflection) that showcase a set of self-regulatory processes that are specifically vital to a person's self-regulation and motivation before, during and after an academic task. SRL microanalysis corresponds directly to Zimmerman's (2000) three-phase model and provides a method to measure these cyclical phase processes. Many self-regulation researchers have argued that this type of measurement is beneficial in its ability to assess authentic moment-to-moment behavioral interactions because this method minimizes response biases and errors associated with retrospective self-reports about behavior or interactions (Cleary et al., 2012).

SRL microanalysis has been used as a measure that "systematically targets individuals' cognitive, motivational, and metacognitive processes as they engage in learning or performance activities" (Cleary et al., 2012, p. 5) across a broad range of tasks over the past decade such as motoric or academic tasks. When utilizing microanalysis Cleary (2011) emphasizes the effective implementation of the following core features of SRL microanalysis: individualized, structured interview protocol, selection of Zimmerman's (2000) SRL processes, develop task-specific questions to target these subprocesses, administer questions aligned with temporal three-phase cyclical model, and verbatim recording and coding of participant's response. All of these criteria were followed in the development and implementation of SRL microanalysis in the current study.

In order to best examine the effects of contextualized forms of feedback during a specific learning task, SRL microanalysis was used to capture SRL sub-processes throughout these activities as recommended by previous studies (Cleary et al., 2012; Cleary et al., 2015). The SRL microanalytic protocol allows the study of SRL processes in real-time before and during the mathematics task, and directly following feedback. This measure will be modeled closely after the work of Callan (2014) in order to utilize the self-regulation questions that Callan (2014) created to specifically study these relevant self-regulatory processes explicitly within the MPS context as well.

The use of SRL microanalysis in measuring SRL processes during a math task has been shown to predict mathematics outcomes/math achievement (Callan, 2014 p. 52). This indicates that the measure of SRL microanalytic interview questions during an MPS task is an effective measurement method because it has the sensitivity to be able to predict achievement across range of math outcomes after controlling for prior achievement. The nature of the MPS task also fits the SRL microanalytic measurement model because this type of measurement is best used with discrete tasks with a clear beginning and end, and math word problems fit this criterion (Hudesman et al., 2011).

Finally, the SRL microanalysis method allows the study of SRL processes across multiple attempts (iteratively) while analyzing processes within the SRL cyclical model multiple times, this study will provide multiple opportunities for students to receive feedback and then practice the question again and thus have opportunities to constructively utilize each type of process feedback to make adaptations in the next practice attempt (Hudesman et al., 2011). As SRL microanalysis enables each sub-process to be measured during real-time engagement in an academic task, questions were presented to participants either immediately before students engaged in an MPS problem, or immediately following the completion of an MPS problem and reception of feedback. This study went through three iterations of the SRL cycle in order to assess for any shifts in SRL processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) throughout data collection of engagement in these processes three times therefore there was opportunity to assess whether feedback impacted the next SRL cycle. In this way this measurement method is sensitive to measuring how the students use the self-generated process feedback and the process feedback to build on successful strategies and modify or replace less effective strategies in the next initiation of the next MPS problem (i.e., beginning with the next processes in the following forethought phase) (Hudesman et al., 2011).

Linking Feedback and SRL

This study sought to add important information to the field of research on feedback and SRL in academic learning by measuring the effects of two widely used types of process feedback and outcome feedback on shifts in SRL processes throughout mathematics practice. Previous studies have examined the effect of one type of feedback in an academic context and recommended that future research compare the causal impact of process and outcome feedback on SRL by using the contextualized method of SRL microanalysis (Cleary et al., 2015). This study sought to provide integrated information on the collaboration of two constructs, SRL and feedback, that have been shown to be two of the most critical positive influences on student academic learning (Corno & Mandinach, 1983; Hattie & Timperley, 2007; Pintrich & De Groot, 1990).

Culotta, Kristjansson, McCallum, & Viola (2006) suggest that outcome feedback would be more efficient in correcting knowledge and improving performance when it is paired with an active learning framework. Nicol and Macfarlane-Dick (2006) also emphasize the responsibility to assess and implement feedback within an SRL framework in order to foster in students a proactive rather than reactive role in generating and using feedback. Rather than assessing simply the match to assessment criteria or quantity of feedback, it is necessary to study feedback with a lens that accounts for ongoing dialogues, reflections, and clarifications, which involves SRL subprocesses before, during, and after the task along with the feedback (Higgins et al., 2001). By analyzing outcome feedback and process feedback within the context of SRL this study addresses the lack of information currently available in the literature regarding the effectiveness of feedback within this dynamic learning context.

Cleary et al. (2015) provides a foundational experimental study that used SRL microanalysis to analyze shifts in student SRL processes following feedback. The authors studied the effect of corrective feedback on medical students' performance on a diagnostic reasoning task, as well as the effect that this outcome feedback had on medical students' shifts in self-efficacy, strategic planning, and metacognitive monitoring. Participants included 71 second-year medical students who had volunteered for participation (65% male students). Students received three extra credit points in their traditional Introduction to Clinical Reasoning course for participation in the study and provided written informed consent. Participation procedures involved a 25 – 30 minute session in which participants were individually administered a diagnostic reasoning task, which instructed students to read a case scenario that pilot testing created to be at such a challenging level that all participants would fail to provide a correct diagnosis. Authors created the task to induce failure so as to examine shifts in students' SRL responses with regard to negative corrective feedback following failure experiences. Students received the same simple corrective feedback of "Sorry, your most likely diagnosis is incorrect" following two distinct failed attempts at providing a correct diagnosis. The SRL microanalytic interview was administered to the participants with regard to prior to participants' attempt of each task and during the first and second iterations of the task. Students attempted the task three times in that students engaged in the diagnostic reasoning two times and then were allowed to preview the task a third time, thus processes occurring at the forethought phase (i.e., self-efficacy and strategic planning) were administered three times. Students engaged in two attempts of the task thus a process occurring at the performance phase (i.e., metacognitive monitoring) was administered two times.

This manipulation of negative corrective feedback provided to novice medical students demonstrated that students' strategic thinking declined following the second instance of negative corrective feedback in comparison to the students' first attempt to plan their strategic thinking prior to receiving negative outcome feedback. Consistent with self-efficacy theory, students' self-efficacy also declined as negative corrective feedback was provided indicating that as students struggled to perform on this task, they had minimal confidence that they could successfully perform the task. Authors indicate that these findings are limited because causal links cannot be claimed and therefore future research should examine the nature of the causal links between self-efficacy and strategic processes of medical students as they perform clinical tasks. Specifically, Cleary et al. (2015) suggest that future research should use SRL microanalytic protocols to examine the differential effects of two types of feedback, such as corrective feedback versus progress feedback, on motivation and self-regulatory processes; the authors state that this type of study should be used to examine causal links between feedback and shifts in SRL. The dissertation addressed this gap by using microanalytic methods to study the impact of these respective two types of feedback. Furthermore the SRL assessment used in this study was iterative. Current research has rarely addressed how regulatory processes and beliefs shift and change during a task in response to different types of feedback and across multiple attempts of an academic task (Cleary et al., 2015).

The different types of process and outcome feedback fit into the SRL cyclical model by being delivered after the performance phase. Figure 4 presents a schematic to conceptualize how feedback and self-monitoring tactics are used to promote strategic reflective thinking within the SRL model. From an instructor's perspective the questions in the SRL phases involve how to facilitate these motivational and strategic processes before the task, as students engage in the task, and how to help students obtain information about task performance or strategy use. The goal of this study was to provide information on how to get students to reflect strategically about performance and adjust and change strategies, in order to provide implications for instructors in how to utilize this model and incorporate feedback (Cleary, 2011). In sum, if instructors were to utilize a lens of SRL at each stage of the academic task, the contextual thinking may involve the types of questions in Figure 4.

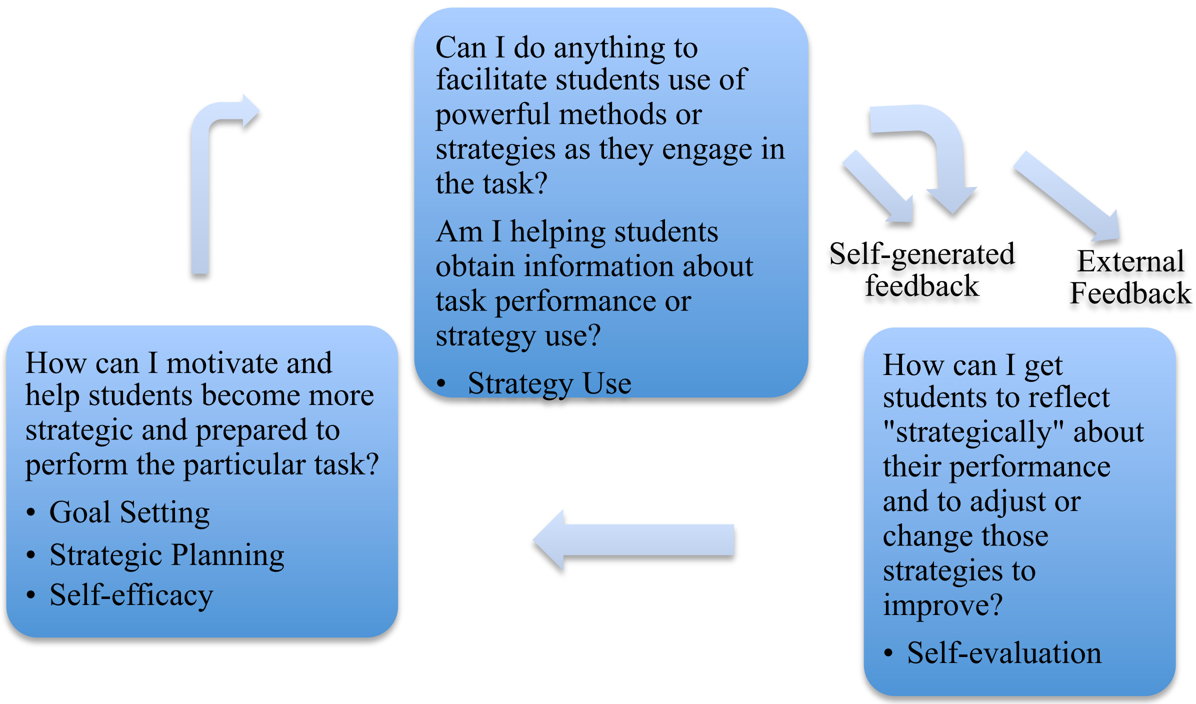

Figure 4. SRL cycle including Instructional Implications and Feedback. Adapted from Cleary, T. J. (2011). Cultivating an Empowering Instructional Context: The Role of Self-Reflection and Process Feedback.

Research has begun to look at feedback within the context of SRL in order to provide practical implications of how feedback is most effective, however, thus far the majority of the current literature studying the relationship between feedback and SRL processes has been limited to assessing how feedback impacts parts of self-regulation such as only the engagement in goal-setting, self-reflection or meta-cognitive questions (Kramarski, & Zeichner, 2001; Van den

Boom, Paas, & Van Merriënboer, 2007; Zellermayer, Salomon, Globerson, & Givon, 1991). SRL occurs at many stages during a discrete learning task; by only collecting data when the student engages in self-monitoring or self-reflection, information is lost regarding how feedback impacts how the student begins a task, sets goals, and cognitively engages in all aspects of the learning task (Butler & Winne, 1995). This study sought to advance this research by studying feedback in reference to multiple phases of the self-regulation process, as well as conducting three full iterations of MPS practice opportunities. In order to address the gap in the literature where there is not yet any information on how feedback affects the self-regulatory processes that occur before, during, and after a learning task, this study examined the shifts in SRL processes before and during a task, and then administered the task two other times in order to assess how EXPF and SRPF, and outcome feedback, impacted the students' engagement in the SRL processes throughout mathematics practice.

Selection of Mathematical Problem Solving Task

Mathematical problem-solving (MPS) was chosen as the task for this study because research has documented a strong connection between SRL and a variety of positive academic outcomes within areas such as MPS (Schunk & Zimmerman, 1998; Kitsantas, 2002). Mathematical problem-solving is an extremely complex important skill that includes the synthesis of multiple general academic skills and is highly related to general mathematical achievement; mathematical problem-solving is also a primary goal of Curriculum standards of NJ and some authors suggest it is a primary goal of mathematics teaching to cultivate problem-solving ability (Bryant, Bryant, & Hammill, 2000; Geary, 2003; Lewis, 1989; National Council of Teachers of Mathematics, 1980; National Council of Teachers of Mathematics, 1989; Wilson, Fernandez, & Hadaway, 1993).

MPS is a cognitively complex area of mathematics that involves the synthesis of multiple math skills and is connected to general math achievement, yet it has not received adequate attention in the literature with regard to feedback; therefore this study sought to examine the effects of feedback on MPS within a systematic, randomized control design. The academic task of engaging in mathematics word problems is also a task with a clear beginning and end, thus it complements the SRL microanalysis method very well because this measurement method requires the target task to be discrete; this enabled feedback to be implemented with each MPS problem and SRL processes were studied surrounding each repetition of mathematics practice.

Students' difficulty in mathematics does not only impact their education in high school, but can have effects that extend beyond graduation. Poor math preparation has been labeled one of the leading causes of academic difficulty for a large portion of incoming two-year and technical college students (Hudesman, Carson, Flugman, Clay, & Isaac, 2011). A conservative analysis of the data regarding college students in 2004 illustrates that 43% of all students at public two-year institutions have enrolled in a remedial course, and 29% of all students at public four-year institutions have enrolled in a remedial class (Strong American Schools, 2008). As students enter college without proper preparation and requiring some form of mathematics remediation in particular, students who have struggled in mathematics in high school are placed at a disadvantage as they enter college and may have to spend funds on repeating or remediating college mathematics courses (Strong American Schools, 2008). Students who take college remediation courses are at-risk because students enrolling in remedial classes are more likely to drop out than students who do not take these courses, and the money they spend on these classes is an unfortunate cost because these classes do not count for college credit (Strong American Schools, 2008). It is increasingly likely that these remedial classes may be necessary for students who lack skills in core content areas as only approximately 20% of jobs can now be done without a postsecondary education, thus these students will need remedial classes to advance in college courses. Therefore it is paramount that students who are struggling in mathematics in high school must be immediately provided with mathematics instruction that has been shown to be produce successful effects, which encompasses the pairing of SRL instruction.

Furthermore, studies that have provided at-risk college students with interventions involving teaching academic mathematics content as well as various study skills, have found that the results do not assist students in attaining their academic goals (Bailey, 2009; Lucas & McCormack, 2007). Conversely, investigations have demonstrated that when students are trained in a self-regulation framework they demonstrate significantly large improvements in their academic achievement and some authors have found SRL produced particularly strong gains in the mathematics content area (Dignath & Buettner, 2008).

Feedback and MPS

When feedback is examined relative to complex tasks, such as reading whole passages or taking unit exams, information about the impact of feedback on performance is lost because feedback is such a dynamic, time-sensitive construct (Butler & Winne, 1995). Therefore, it is important to analyze the effect of feedback within immediate tasks, such as mathematical problem-solving in which the effect of feedback provided after individual math problems can be assessed directly following each iteration of the math problems. Overall, studies have indicated that learning with feedback is preferable to learning without feedback (McDaniel and Fisher, 1991; Zellermayer et al., 1991).

Kramarski and Zeichner (2001) implemented two types of feedback to analyze the effect on mathematical reasoning in a computerized environment. Metacognitive feedback was based on self-regulation learning by using metacognitive questions as cues to facilitate students' understanding of the problem and result feedback provided cues pertaining only to the final outcome, therefore result feedback aligned with the current study's definition of outcome feedback and the metacognitive feedback aligned with the current study's definition of EXPF. It was hypothesized that the delivery of EXPF (i.e., labeled metacognitive feedback) would be more effective than providing outcome feedback because the process feedback would initiate students' development of internal feedback by cuing students to understand the content and structure of the problem as a way to solve the problem. Karmarski and Zeichner (2001) randomly assigned classrooms of 186 eleventh grade students to conditions receiving either type of feedback. All students received the same mathematical series within a computerized unit and the computer provided the metacognitive feedback or the result feedback; students in each group received an explanation of the importance of using that type of feedback at the start of the sessions. Metacognitive feedback responded to student's completion of problems by asking questions about types of strategies that are appropriate for the task and why, whereas, result feedback responded to problem responses by remarking on accuracy such as by telling students they made a mistake or they did a wonderful job. Results showed that students receiving the process feedback outperformed the outcome feedback group on all mathematical measures, and also demonstrated a more varied response format in that these process feedback students provided their mathematical reasoning in a richer format. Authors extrapolate on the successful impact of this type of computerized EXPF on students mathematical reasoning and suggest that EXPF is effective with math performance because it teaches students that their learning processes can be regulated by themselves and are their responsibility. Therefore Kramarski and Zeichner (2001) suggest that EXPF successfully impacts mathematical reasoning in part because it targets students' focus on strategies, and therefore should enhance SRL processes such as thinking about similarities and differences between previous and new asks, comprehending the problem before attempting a solution, and reflecting on the use of appropriate strategies which in this study enhanced student's focus on decision making and therefore enhanced mathematical reasoning.

Linking SRL and MPS

Recent years have shown increased interest in the role of metacognition and SRL and in mathematics education (Butler & Winne, 1995; Hacker, 1998; Mevarech & Kramarski, 1997) due to the connection between SRL and problem-solving with activities including evaluating goals, thinking of strategies, and choosing the most appropriate strategy for solving a problem. The area of mathematics is viewed as an active process in which learners assume control and agency over their own learning and problem-solving activities, which indicates that self-regulation comprises a component of effective problem-solving learning (De Corte, Verschaffel, & Op't Eynde, 2000). Researchers emphasize the importance and centrality of self-regulation as a major objective of mathematics education and as a crucial characteristic of effective mathematics learning, yet literature demonstrates that students of various ages have specific weaknesses in self-regulatory processes within this academic area which therefore underlines the need to continue to study ways to assess SRL within mathematical learning (De Corte et al., 2000) to determine ways to enhance it such as through instructional methods of feedback.

Instruction that teaches students with an SRL approach, meaning that the model emphasizes a metacognitive style of learning, has shown to be highly effective with not only helping students' academic performance but particularly demonstrating strong results in mathematics performance (Hudesman, Carson, Flugman, Clay, & Isaac, 2011). However, reports indicate that there are difficulties with implementing an SRL program for mathematics because it increases various demands on math instructors including requiring that teachers gather increased information on students' assessment scores, document the link between outcome performance and students' SRL behaviors, and present information clearly to students in order to strengthen mathematical comprehension and bridge the relationship to SRL behaviors. This integration and collection of data for results regarding SRL behaviors and mathematics performance involves time intensive activities completed by the instructor. Since it has been documented that SRL instruction in mathematics can produce impressive improvements in students' math performance, it is important that future research examines ways to streamline how to provide students' mathematics instruction that allows teachers to efficiently establish a link to SRL within the teaching module (Hudesman et al., 2011). One way to organize mathematics instruction within an SRL framework is examined in this study by instructing students in a mathematical problem solving strategy that is founded on SRL principles. In addition, by providing two types of process feedback that both direct students to focus on strategies in two different ways also coincides with the SRL principle of strategically engaging in tasks throughout the SRL cycle. Therefore, this study examined how to effectively enhance students' MPS performance by utilizing a simplified MPS strategy with SRL principles and providing feedback in a way that was sensitive to the SRL cyclical model. This study analyzed how participants' SRL beliefs and cognitions (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) change throughout three MPS problems. Rather than collecting data on these processes only at single points throughout the experiment, the current study examined shifts in participants' motivation belief and regulatory processes as participants engaged in the MPS academic task across two iterations of the task.

MPS Strategy Instruction: Implications for Delivery of Feedback and Impact on SRL

One of the causes of students' errors in mathematics is the students' misuse of self-regulatory strategies (such as failed cognitive control or incorrect strategy utilization) (Radatz, 1979). By studying MPS within the context of SRL, this study further assessed how students engage in this primary regulatory strategy of error correction. This study also added the element of feedback to understand how two types of information regarding students' errors in a mathematical problem-solving task impact SRL and performance. As schools undergo the changing of core curriculum standards and work to provide the best education to their students in response to this research, one area that must be addressed is problem solving as this is specifically referred to as one of the first four standards emphasized by the state of New Jersey (New Jersey Mathematics Coalition, 1996). According to the New Jersey Department Of Education (NJDOE) Core Curriculum Standards (1996-2010), to receive a high school diploma, students must perform at proficient or advanced proficient levels of achievement in all sections of the HSPA and other standardized testing, in which mathematics is a core subject. Partially proficient is defined as a student-achieved score below the cut score; this marks a solid understanding of the content measured by an individual section of any State assessment (NJDOE Core Curriculum Standards,1996-2010). Proficient refers to a student-achieved score at or above the cut score, also marking a solid understanding of the content. It is important to enhance students' problem-solving skills because this helps students do well in courses and/or statewide tests, which helps students advance in their holistic education.

Research in different academic domains shows that students taught strategies typically improve their skills and strategy instruction is moderately to highly successful regardless of the strategy or instructional method (Schunk & Swartz, 1993; Schunk & Rice, 1999; Pressley et al., 1990), thus this study also included direct instruction in an MPS strategy in order to analyze the effect of this instruction when paired with feedback. Schoenfeld (1982) demonstrated that when students are given direct instruction in problem solving skills students show marked improvement in problem solving performance; this continued to be true even when students were asked to complete math problems that were different than the instructional course. Comparatively, experts use metacognitive behaviors to stay on track, and are equipped with a wide variety of problem solving techniques and efficient ways of using and deciding which ways to use these strategies (Schoenfeld, 1982). Schoenfeld (1982) suggests that one reason that students exhibit poor problem solving performance is due to the absence of these types of metacognitive behaviors. The current study responded to Schoenfeld's (1982) work by further examining the relationship between students' use of self-regulatory strategies during mathematical problem solving to look for the presence of these metacognitive behaviors and strategies, and to determine how feedback impacts the engagement of these strategies. This study assessed how students engage in well-defined metacognitive behaviors during problem solving in order to add to the research of the parameters of the impact of SRPF or EXPF on these metacognitive behaviors, as well as inform the relationship between SRL processes and high school students' problem-solving performance..

Most studies in academic contexts such as writing, science, and math include some strategy instruction because research in many domains shows that students taught strategies typically improve their skills (Pressley et al., 1990; Schunk & Swartz; 1993). In particular, direct instruction in MPS skills and emphasis on strategy in problem solving instruction has been connected with students' marked improvement in problem solving performance (Schoenfeld, 1982; Pape & Wang, 2003). This study paired feedback with this other strong predictor of achievement, direct strategy instruction, by providing all students with direct training of a simplified, evidence-based mathematics problem solving strategy. Students receive different types of feedback depending on conditions, but all students received the benefit of this direct instruction, thus enabling the analysis of the differential effect of feedback types in addition to the direct instruction to discern which type is beneficial for SRL processes and MPS performance. The ability to implement multiple learning strategies and adjust those strategies as needed to facilitate one's progress in successful academic task completion has been a trait of successful learners (Paris & Paris, 2001). In order to support learners towards this end, it is recommended that time be provided for students to learn and become comfortable with different strategies through modeling of strategies and provision of guided student practice with the strategies. This study's inclusion of a strategy instruction session was another component to help participants become independent strategy users.

The MPS strategy instruction in the current study involved explicitly explaining an MPS strategy to participants, as well as modeling and demonstrating how this strategy is used, and what skills are involved in the strategy (Zimmerman, 2008). During modeling the examiner explained the thought processes necessary for completing the MPS problems with the MPS strategy so that students would be more able to comprehend and absorb the strategy as their own process (Boekaerts & Corno, 2005). Research has demonstrated that this type of strategic instruction, though not necessary for all students, can be a superior initial method for encouraging students to be more self-regulative and also may be essential for most students that fail to independently use SRL strategies effectively (Levy, 1996; Zimmerman, 2000).

The emphasis of strategies is inherent in the current burgeoning research that advocating for a SRL approach in utilizing interventions that teach students to develop and use self-regulation to better use feedback and subsequently optimize learning (Hudesman, Zimmerman, & Flugman, 2010; Zimmerman, Moylan, Hudesman, White, & Flugman, 2011). Hudesman, Crosby, Flugman, Issac, Everson and Clay (2013) advocate that a key tenant of a successful SRL intervention includes that students acquire more feedback each time they complete an SRL cycle and with that feedback students advance closer to achieving their goals. Hudesman et al. (2013) state that throughout this combination of a focus on SRL and feedback "students begin to understand that learning is directly related to experimenting with different strategies" (p. 3), which embodies a vital shift from a perspective that relates achievement to ability or other external factors (Zimmerman, 2002). Research also specifically advocates the combination of process feedback and strategy instruction can be useful to help a student adapt their approach to the next math problem because process feedback provides more detailed information as well as information that is specifically focused on strategy (Black & William, 1998; Hattie & Timperley, 2007; Kluger & DeNisi, 1996, Shute, 2008).

Instruction and development of 5-step MPS strategy. All participants received training in a general problem-solving strategy that was created by merging the research-based strategy of Montague's (1992) and the problem-solving strategy utilized in the Self-Regulation Empowerment Program (SREP) problem-solving instruction (Cleary & Zimmerman, 2004). Montague's (1992) principles merge metacognitive and cognitive steps to provide students with a holistic problem-solving strategy. The P^3-ESP presents a structured strategy to approach problem-solving and also includes specific ways to train students in the strategy involving guided practice and modeling components. Both strategy templates were used to create the strategy instruction for this study in order to provide a more simplified yet thorough strategy that encompassed key problem-solving strategy steps across the research regarding both of these strategies. The current strategy instruction also includes similarities to a previously used IMPROVE method that was used in prior research to provide students with cues for students to engage in mathematical reasoning with the use of metacognitive questions focusing on: (a) the nature of the problem, (b) similarities and differences between previous and new knowledge, and (c) use of strategies appropriate for solving the problem (Kramarski & Zeichner, 2001; Mevarech & Kramarski, 1997).

Both Montague's (1992) principles, which emphasize that students be taught a combination of 7 cognitive steps and 3 metacognitive strategies, and the SREP strategy, which embodies six self-regulatory steps, present a structured strategy to approach problem-solving. The six steps of P^3-ESP include: 1) Identify Problem type, 2) Determine key Parts of the question, 3) Draw a Picture (Situational model), 4) Write out a numerical Equation (mathematical problem), 5) Solve the problem without making mistakes, 6) Proofread and check answer. Montague's (1992) cognitive steps include: (a) Read for understanding, (b) Paraphrase your own words, (c) Visualize a picture or diagram, (d) Hypothesize a plan to solve the problem, (e) Estimate the answer, (f) Compute the arithmetic, and (g) Check to make sure everything is right. Within these seven processes Montague adds the metacognitive focus of SAY, ASK, and CHECK in which the student is taught to engage in these three self-monitoring steps for each cognitive process.

The goal of the current study's strategy instruction was for students to attain a higher level of accuracy when solving math problems that are assigned for homework or on tests by providing knowledge of specific procedures to problem-solve. This metacognitive strategy sought to help students plan or reflect on the nature of the problem prior to solving it and monitor and evaluate the accuracy of one's answers. The cue card used in the current study was modeled from those of Montague (1992) and SREP's P^3-ESP strategy was used to break down the description and use of the simple 5-step strategy used in this study: 1) Determine key Parts of the question, 2) Draw a picture (situational model, 3) Write out a numerical Equation (mathematical problem), 4) Solve the Problem, 5) Proofread and check answer (Cleary, 2015; Chung & Tam, 2005; Montague, 2008).

Appendix B: Research Questions and Analyses

	Research Question	Hypothesis	Measures	Statistical Analysis
1.	Are there statistically significant differences among treatment groups (i.e., SRPF, EXPF, and control) in terms of self-regulated learning processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use)?	Students in the SRPF group will demonstrate significantly higher SRL behaviors (i.e., overall self-efficacy, goal-setting, strategic planning, and strategy use) than their counterparts in the EXPF group and the control group.	SRL microanalytic interview (see Appendix E)	SRL Coding Process (see Appendix F) Two-way ANOVA
2.	Are there statistically significant differences among treatment groups (i.e., SRPF, EXPF, and control) in terms of mathematics performance (i.e., as measured by MPS practice problems and posttest problems)	Students in both process feedback conditions will outperform the control condition by evidencing higher mathematics performance. In addition, the SRPF group will demonstrate higher MPS performance due to increased use of SRL processes and focus on strategy, which are hypothesized to have positive impacts on academic performance (Hattie & Timperley, 2007).		
a.	Are there statistically significant differences among treatment groups (i.e., SRPF, EXPF, and control) in terms of performance on the MPS problems during the MPS practice session?	Students within the SRPF will demonstrate significantly higher performance on MPS problem during the MPS practice session.	MPS Problems during Practice Session (see Appendix E)	Adapted Coding Process (see Appendix G) Two-way ANOVA
b.	Are there statistically significant differences among treatment groups (i.e., SRPF, EXPF, and control) in terms of performance on the MPS problems during the MPS Posttest problems?	Students within the SRPF will demonstrate significantly higher performance on MPS problem on the Posttest problems.	MPS Problems during Posttest Session (see Appendix E)	Adapted Coding Process (see Appendix G) ANOVA
3.	Are there statistically significant shifts in self-regulatory processes (i.e., self-efficacy, goal-setting, strategic planning, and strategy use) within each of the feedback groups (i.e., SRPF, EXPF, and control)?	Exploratory research question with anticipation that students in the SRPF and EXPF experimental condition will produce significantly more adaptive shifts in self-regulatory processes than the students in the control condition.	SRL microanalytic interview (see Appendix E)	SRL Coding Process (see Appendix F) Repeated Measures ANOVA

Appendix C: IRB Approval Forms

RUTGERS

Office of Research and Regulatory Affairs
Arts and Sciences IRB
Rutgers, The State University of New Jersey
335 George Street / Liberty Plaza / Suite 3200
New Brunswick, NJ 08901

orra.rutgers.edu/artsci

732-235-9806

March 24, 2015

P.I. Name: Gonzales
Protocol #: E15-587

Gabrielle Gonzales
152 Frelinghuysen Road
Piscataway NJ

Dear Gabrielle Gonzales:

This project identified below has been approved for exemption under one of the six categories noted in 45 CFR 46, and as noted below:

Protocol Title: "Examining the Effects of Process Feedback on High School Students' Shifts in Self-Regulated Learning and Mathematics Performance"

Exemption Date: 3/23/2015 **Exempt Category:** 1

This exemption is based on the following assumptions:

- **This Approval** - The research will be conducted according to the most recent version of the protocol that was submitted.
- **Reporting** – ORSP must be immediately informed of any injuries to subjects that occur and/or problems that arise, in the course of your research;
- **Modifications** – Any proposed changes MUST be submitted to the IRB as an amendment for review and approval prior to implementation;
- **Consent Form (s)** – Each person who signs a consent document will be given a copy of that document, if you are using such documents in your research. The Principal Investigator must retain all signed documents for at least three years after the conclusion of the research;

Additional Notes:	▪ **None**

Failure to comply with these conditions will result in withdrawal of this approval.
Please note that the IRB has the authority to observe, or have a third party observe, the consent process or the research itself. The Federal-wide Assurance (FWA) number for the Rutgers University IRB is FWA00003913; this number may be requested on funding applications or by collaborators.

Sincerely yours,

Michelle Watkins

Acting For--
Beverly Tepper, Ph.D.
Professor, Department of Food Science
IRB Chair, Arts and Sciences Institutional Review Board
Rutgers, The State University of New Jersey

cc: Timothy Cleary

(MW:nh)

RUTGERS

Office of Research and Regulatory Affairs
Arts and Sciences IRB
Rutgers, The State University of New Jersey
335 George Street / Liberty Plaza / Suite 3200
New Brunswick, NJ 08901

orra.rutgers.edu/artsci
732-235-9806

May 15, 2015

P.I. Name: Gonzales
Protocol #: E15-587

Gabrielle Gonzales
152 Frelinghuysen Road
Piscataway NJ

Dear Gabrielle Gonzales:

This project identified below has been approved for exemption under one of the six categories noted in 45 CFR 46, and as noted below:

Protocol Title: "Examining the Effects of Process Feedback on High School Students' Shifts in Self-Regulated Learning and Mathematics Performance"

Amendment Exemption Date: 5/14/2015 **Exempt Category:** 1

This exemption is based on the following assumptions:

- **This Approval** - The research will be conducted according to the most recent version of the protocol that was submitted.
- **Reporting** – ORSP must be immediately informed of any injuries to subjects that occur and/or problems that arise, in the course of your research;
- **Modifications** – Any proposed changes MUST be submitted to the IRB as an amendment for review and approval prior to implementation;
- **Consent Form (s)** – Each person who signs a consent document will be given a copy of that document, if you are using such documents in your research. The Principal Investigator must retain all signed documents for at least three years after the conclusion of the research;

Additional Notes:	**Administrative Amendment to Exemption Granted on 5/14/15 for (1) Revised eligibility criteria to include all Princeton High School students who are currently enrolled in Algebra II at the target high school for the year 2014-2015; (2) Increase subject enrollment from 56 to an additional 65 for a total of 121 subjects in order to reach a targeted subject enrollment of 56; (3) add incentive for students, such as extra credit or homework pass.**

Failure to comply with these conditions will result in withdrawal of this approval.
Please note that the IRB has the authority to observe, or have a third party observe, the consent process or the research itself. The Federal-wide Assurance (FWA) number for the Rutgers University IRB is FWA00003913; this number may be requested on funding applications or by collaborators.

Sincerely yours,

Farah Anwar

Acting For--
Beverly Tepper, Ph.D.
Professor, Department of Food Science
IRB Chair, Arts and Sciences Institutional Review Board
Rutgers, The State University of New Jersey

cc: Timothy Cleary

Appendix D: Recruitment Notices, Parental Consent, and Student Assent

Princeton Public Schools
Live to Learn, Learn to Live

Gabrielle Gonzales, Psy.M.
School Psychology Intern
Princeton High School
151 Moore Street
Princeton, NJ 08540
609-806-4284 x3523
gabrielle_gonzales@princetonk12.org

Date: May 14, 2015

Dear Princeton High School Parent,

You are receiving this letter because your child has been found to be eligible to participate in a research study being conducted at Princeton High School. All Princeton High School students enrolled in Algebra II are eligible to participate in this study as these students have been exposed to the level of problem-solving material used in this study.

A new component has been added to this research. All students that participate in this study will receive an incentive determined by their classroom Algebra II teacher. This incentive will be provided solely on participation in this study. Participation will provide your child with a single, individually administered mathematics practice session that teaches your child a strategy for solving math problems and matches the material your child has been exposed to in his or her Algebra II class.

Participation in this research is voluntary and your child will not be involved in this research without your informed consent. In order to provide consent the agreement form must have your signature and be provided to Ms. Gonzales either by bringing the signed document to the school or by scanning the signed document and emailing it as an attachment to Ms. Gonzales. Please review the attached documents to learn more about this exciting opportunity we are offering for the Spring 2015. Enclosed is a letter from our Principal as well as documents explaining the nature of the research being conducted and how to provide voluntary consent to include your child in this study. **If you have already provided consent, please accept this letter as information about the changes and know that your child will receive the incentive determined by his or her classroom Algebra II teacher for his or her participation.**

Thank you for your time,

____

Gabrielle Gonzales, Psy.M.
School Psychologist, Intern, Princeton High School

Princeton Public Schools
Live to Learn, Learn to Live

PRINCETON PUBLIC SCHOOLS
Princeton High School • 151 Moore Street • Princeton, NJ 08540

March 10, 2015

Dear Princeton High School Parent,

I am writing to inform you about an exciting opportunity we are providing for our students for the Spring of 2015. This year we have a School Psychologist, Ms. Gabrielle Gonzales, who is completing her Doctoral Internship hours at Princeton High School. She has been working full-time at Princeton High School serving in a variety of roles to help provide holistic support to our students. As a part of her Doctoral Internship hours she will be conducting a research project to gain vital information about how different types of academic feedback are useful for enhancing high school students' motivational beliefs and strategic approaches to mathematical problem solving.

Your child's enrollment in our Algebra II classes, one of approximately 80 students, enables him/her to participate in this research. Attached is important information regarding this opportunity. If you are interested in having your child take part in this research, please complete the parent release form and return it to Ms. Gonzales.

Please note that individual student information will be kept private and will not be shared with school personnel in any way.

Attached is a synopsis of this opportunity.

Sincerely,

Gary R. Snyder
Principal

Attachments:
Description of Participation
Informed Consent Agreement

Princeton Public Schools
Live to Learn, Learn to Live

PRINCETON PUBLIC SCHOOLS

Princeton High School • 151 Moore Street • Princeton, NJ 08540

Description of Participation:

Participation will provide students the opportunity to engage in a single, individualized mathematics practice session in which all students will be taught an evidence-based mathematical problem-solving strategy, and will be led through a practice session of mathematical problems that match the Algebra II curriculum that students are currently experiencing in class. Students will be provided different types of feedback and asked about different ways that they manage their motivations and strategic thoughts throughout the task. As the entire session has been created to match the curriculum that Princeton High School students are receiving in the Algebra II classes, students may find this session to be useful in providing new insight and strategies of approaching the mathematics content that they have been working on this year in class. If a student participates in this research the student will engage in one individually administered session involving this experience of mathematics practice and the delivery of feedback and strategy instruction. Students who participate will be excused from one class period to engage in the single session, as students will be engaging in an alternative learning experience for that period.

Princeton
Public Schools
Live to Learn, Learn to Live

Office of Curriculum and Instruction
25 Valley Road, Princeton, New Jersey 08540
609.806.4203

January 28, 2015

Arts and Sciences Institutional Review Board for the Protection of Human Subjects
Office of Research and Regulatory Affairs
Rutgers University, The State University of New Jersey
335 George Street
Liberty Plaza / 3rd Floor / Suite 3200
New Brunswick, NJ 08901

To Whom It May Concern:

I am writing a letter of support for Gabrielle Gonzales' research project entitled, "An Experimental Study of the Effect of Two Types of Feedback on the Self-Regulated Learning of High School Students Within the Context of Mathematical Problem Solving: A Comparison of the Effect of Process Feedback and Corrective Feedback."

Ms. Gonzales, Psy.M., has received formal informed consent from the Princeton Public School's Student Achievement Committee. Ms. Gonzales has informed the Princeton Student Achievement Committee of the nature of this study including its focus on feedback and self-regulation assessments in mathematics for high school students. I understand that this study will take place with data collection occurring during the school day. Ms. Gonzales will individually administer the mathematical problems, feedback, and self-regulation measures to students at Princeton High School during one session during the spring of 2015. Ms. Gonzales will also utilize student records and teacher recommendations to determine which students are eligible for participation by meeting criteria for struggling in mathematics. All information will be de-identified and the results of this research will not be formally linked with Princeton's educational facility.

It is my pleasure to be a part of this project because of the clear educational and professional benefit to our students and teachers. The Student Achievement Committee, which includes Board of Education members of the Princeton Public School District, approved this project on December 12, 2014.

Please let me know if you have any questions.

Best wishes,

Bonnie Lehet

Bonnie Lehet
Assistant Superintendent for Curriculum and Instruction
Phone: 609-806-4203 Email: bonnie_lehet@princetonk12.org

PARENTAL INFORMED CONSENT AGREEMENT

Project Title: Examining the Effects of Process Feedback on High School Students' Shifts in Self-Regulated Learning and Mathematics Performance

Please read this consent agreement carefully before you decide to provide consent for your child to participate in the study.

Your child is invited to participate in a research study being conducted by Gabrielle Gonzales, a school psychologist completing Doctoral Internship hours at Princeton High School. Ms. Gonzales is also a doctoral student in the Graduate School of Applied and Professional Psychology at Rutgers University.

Purpose of this study:
The purpose of this research is to determine which type of feedback or information is most effective at improving high school students' regulation, motivation, and mathematics performance.

What will your child do in this study:
Your child will participate in a mathematics practice session. First, your child will receive individual instruction on a strategy for how to solve mathematics word problems. Your child will be taught the components of the strategy and guided in practicing the use of the strategy. Then, your child will be administered three math problems. For each math problem your child will be provided a type of feedback to provide information on your child's performance. Depending on group assignment, each child will receive a different type of feedback that is supported by the literature and commonly used in educational settings with high school students. Your child will also be administered interview questions asking about his or her regulation during the mathematics task. The last part of this single 45-minute session will involve your child's completion of two final mathematics questions to assess the impact of the session on mathematics performance. All mathematics word problems have been created to match what your child has been exposed to in his or her Algebra II class at Princeton High School.

Time Required:
The total time commitment will be about 45 minutes. This session will take place at Princeton High School and will be scheduled to be least disruptive to your child's class schedule. Your child will be excused from one class period with the positive permission of his or her classroom teacher, as he or she will be engaging in a learning activity with the researcher.

Risks: There are no foreseeable risks involved in your child's participation in this study.

Benefits: There are no direct benefits to your child for participating in this research study. Your child may benefit from the services he or she receives and may also learn new things about his or her learning style specific to mathematics. Your child may benefit from learning a research-based mathematical problem solving strategy that may improve his or her ability to successfully engage in solving word problems. We hope that the knowledge that we obtain from your child's participation, and the participation of other volunteers, may help us to better understand how educators can provide feedback and information to best support students' motivational processes and thoughtful approaches to learning and performance in mathematics.

Confidentiality:
This research is confidential. Confidential means that the research records will include some information about your child and this information will be stored in such a manner that some linkage between your child's identity and his or her responses in the research exists. Some of the information collected about your child includes your child's name and grades in mathematics classes at Princeton High School. The information in the study records will be kept strictly confidential. Data will be stored securely in a restricted-access computer and will be made available only to persons conducting the study. Identifying information will be replaced by special codes. Papers with your child's name will be maintained in a secure location. Only the research team will have access to the data and protocols of this project.

If a report of this study is published, or the results are presented at a professional conference, only group results will be discussed to further reduce the likelihood of sharing private information. All study data (i.e., protocols, surveys, and other materials gathered during this project) will be kept for five years following completion of the study. After that time, all data will be shredded and destroyed. The identity of the participants will be protected by not including their name or the name of the school in any oral or written documentation of this project.

Voluntary participation:
Your consent for your child's participation in the study is completely voluntary.

Right to withdraw from the study:
You have the right to withdraw your child from the study activities at any time without penalty.

How to withdraw from the study:
Please contact Ms. Gonzales with the contact information provided below.

Payment:
No payment will be provided for participating in the study.

If you have questions about the study or the study procedures, contact:
Researcher's Name: Gabrielle Gonzales, Princeton High School, 151 Moore Street Princeton, NJ 08540; E-mail: gabrielle_gonzales@princetonk12.org, Telephone: 609-806-4280 extension 3523.

If you or your child has any questions about his or her rights in the study, contact:
The Institutional Review Board (a committee that reviews research studies in order to protect those who participate). Please contact an IRB Administrator at the Rutgers University, Arts and Sciences IRB:

Institutional Review Board
Rutgers University, the State University of New Jersey

Liberty Plaza / Suite 3200
335 George Street, 3rd Floor
New Brunswick, NJ 08901
Phone: 732-235-9806
Email: humansubjects@orsp.rutgers.edu

Agreement:
I agree for my child to participate in the research study described above.
You will be given a copy of this consent form for your records.

Please Sign below and return this form if you agree to allow your child to participate in this research study:

Name of Child (Print) ____

Name of Parent/Legal Guardian (Print) ____

Parent/Legal Guardian's Signature ____________________ Date _____________________

Principal Investigator Signature ______________________ Date ___________________

Audio Addendum to Consent Form

You have already agreed to allow your child to participate in a research study entitled: "Examining the Effects of Two Types of Process Feedback on Shifts in Self-Regulated Learning and Mathematics Performance of High School Students" conducted by Gabrielle Gonzales. We are asking for your permission to allow us to audiotape (i.e., record the sound) the session your child will participate in as part of that research study.

You do not have to agree allow your child to be audio recorded in order to participate in the main part of the study. The recording will be used for analysis by the research team in order to ensure that interview questions are accurately transcribed.

The recording will not include the subject's name or any other identification of the subject.

The recording will be stored in a password-protected file and linked with a code to subject's identity and will be retained for five years following the completion of the study procedures and destroyed after that time.

Your signature on this form grants the research team permission to audio record your child as described above during participation in the above-referenced study. The investigator will not use the recording for any other reason than those stated in the consent form without your written permission.

Name of Child (Print) ____

Name of Parent/Legal Guardian (Print) ____

Parent/Legal Guardian's Signature _____________________ Date ______________________

Principal Investigator Signature _____________________ Date __________________

For IRB Use Only. This Section Must be Included on the Consent Form and Cannot Be Altered Except For Updates to the Version Date.

IRB Stamp Box	IRB Stamp Box	Version Date: v1.0 Page 151

STUDENT INFORMED ASSENT AGREEMENT

Project Title: Examining the Effects of Process Feedback on High School Students' Shifts in Self-Regulated Learning and Mathematics Performance

Please read this agreement carefully before you decide to participate in the study.

You are invited to participate in a research study being conducted by Gabrielle Gonzales, a school psychologist completing Doctoral Internship hours at Princeton High School.

Purpose of this study:
The purpose of this research is to understand what types of information educators can provide students to best help students strategically engage in solving mathematics word problems.

What you will do in this study:
You will participate in a mathematics practice session. You will be taught a strategy for how to solve mathematics word problems. Then, you will be administered three math problems. For each math problem you will be provided information on your performance. You will also be asked questions asking about your motivation and thinking during the mathematics task. The last part of this single 45-minute session will ask you to complete two final mathematics questions. All mathematics word problems have been created to match what you have been exposed to in your Algebra II class at Princeton High School.

Time Required:
The total time commitment will be about 45 minutes. This session will take place at Princeton High School and will be scheduled to be least disruptive to your class schedule. You will be excused from one class period with the positive permission of your classroom teacher, as you will be engaging in a learning activity with the researcher.

Risks: There are no foreseeable risks involved in your participation in this study.

Benefits: There are no direct benefits to you for participating in this research study. You may benefit from the services you receive and may also learn new things about your learning style specific to mathematics. You may benefit from learning a research-based mathematical problem solving strategy that may improve your ability to successfully engage in solving word problems. We hope that the knowledge that we obtain from your participation, and the participation of other volunteers, may help us to better understand how educators can provide feedback and information to best support students' approaches to learning and performance in mathematics.

Confidentiality:
This research is confidential. Confidential means that the research records will include some information about you and this information will be stored in such a manner that some linkage between your identity and responses in the research exists. The information in the study records will be kept strictly private. Data will be stored securely in a restricted-access computer and will be made available only to persons conducting the study. Identifying information will be replaced

by special codes. Papers with your name will be maintained in a secure location. Only the research team will have access to the data and protocols of this project.

If a report of this study is published, or the results are presented at a professional conference, only group results will be discussed to further reduce the likelihood of sharing private information. All study data (i.e., protocols, surveys, and other materials gathered during this project) will be kept for five years following completion of the study. After that time, all data will be shredded and destroyed. The identity of the participants will be protected by not including their name or the name of the school in any oral or written documentation of this project.

Voluntary participation:
Your participation in the study is completely voluntary.

Right to withdraw from the study:
You have the right to withdraw from the study at any time without penalty.

How to withdraw from the study:
Please contact Ms. Gonzales with the contact information provided below.

Payment:
No payment will be provided for participating in the study.

If you have questions about the study or the study procedures, contact:
Researcher's Name: Gabrielle Gonzales, Princeton High School, 151 Moore Street Princeton, NJ 08540; E-mail: gabrielle_gonzales@princetonk12.org, Telephone: 609-806-4280 extension 3523.

If you have any questions about your rights in the study, contact:
The Institutional Review Board (a committee that reviews research studies in order to protect those who participate). Please contact an IRB Administrator at the Rutgers University, Arts and Sciences IRB:

Institutional Review Board
Rutgers University, the State University of New Jersey
Liberty Plaza / Suite 3200
335 George Street, 3rd Floor
New Brunswick, NJ 08901
Phone: 732-235-9806
Email: humansubjects@orsp.rutgers.edu

Agreement:
I agree to participate in the research study described above.

Please Sign below if you agree to participate in this research study:

Name of Student (Print) ____

Student's Signature ____________________________Date ____________________

Principal Investigator Signature ______________________ Date ___________________

Audio Addendum to Assent Form

You have already agreed to participate in a research study entitled: "Examining the Effects of Two Types of Process Feedback on Shifts in Self-Regulated Learning and Mathematics Performance of High School Students" conducted by Gabrielle Gonzales. We are asking for your permission to allow us to audiotape (i.e., record the sound) the session you will participate in as part of that research study.

You do not have to agree allow the session to be audio recorded in order to participate in the study. The recording will be used for analysis by the research team in order to ensure that interview questions are accurately transcribed.

The recording will not include the subject's name or any other identification of the subject.

The recording will be stored in a password-protected file and linked with a code to subject's identity and will be retained for five years following the completion of the study procedures and destroyed after that time.

Your signature on this form grants the research team permission to audio record your session as described above during participation in the above-referenced study. The investigator will not use the recording for any other reason than those stated in the consent form without your written permission.

Name of Student (Print) ____

Student's Signature __________________________Date ___________________

Principal Investigator Signature ____________________ Date _________________

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IRB Stamp Box	IRB Stamp Box

Version Date: v1.0

Appendix E: SRL Microanalytic Protocol

Cover Page

Examiner Name__________________________________

Student Name: ___________________________________

Date: ____

Student ID #: ____________________________________

Was this protocol recorded verbatim?____

Verbatim:

- **Question 1_____________________(Time:___________)**
- **Question 2_____________________(Time:___________)**
- **Question 3_____________________(Time:___________)**
- **Question 4 ____________________(Time:____________)**

II. Microanalytic Interview

MATHEMATICAL PROBLEM SOLVING TASK

General Overview of Study:

a. Review Informed Consent & Participant Rights

- Parents have already completed informed consent.
- Overview following participant rights and answer any questions s/he may have.
  - Voluntary participation
  - Right to not answer any questions or stop at any time
  - Confidentiality (& exceptions)
  - Won't affect grades

Say, **"Before we start, I want you to take a moment to review the informed consent document. If you have any questions or concerns, please don't hesitate to ask."**

Once the participant has read the document: Ask**, "Do you have any questions for me?**

b. Introduction of Math Problem Solving Strategy

☐ NOTE: All students in all three conditions will be instructed on the Math Problem-Solving strategy utilizing the Strategy Cue Card. Goals of the module are to provide students with a problem-solving framework to solve math problems and to focus students' strategic thinking skills when solving math problems. Script and directions for training in this strategy will follow the Module used in the SREP program (Cleary, 2015).

Directions:

Say, **"Have you ever been solving a math problem and you think you did it correctly but it was actually wrong? Or how about you start solving a problem and halfway through the problem you realize that you are doing it completely wrong?** Engage student(s) in this discussion. **This can be really frustrating because you probably know how to solve many parts of the problem, but you just can't get the correct answer. Sometimes this happens because we make careless mistakes or perform the steps of a procedure wrong. What I would like to talk about today is a 5-Step Math Problem-Solving strategy. This strategy can help you make sure you are thinking about the problem in the right way so that you can get the correct answer"**

> **Primary Theme**: To convey to students that their experiences in incorrectly solving math problems are common for many students but they can be improved.

a) 5-Step Strategy Cue Card.

Show the student the Strategy Cue Card.

1) Determine key **Parts** of the Problem

___

___

___

2) Draw a Picture (Situational model)

3) Write out a numerical **Equation** (mathematical problem)

4) **Solve** the Problem

5) **Proofread** and check answer

b) Direct Instruction

Say, **"This strategy is like a guide. It shows several different questions that you should answer in your head when solving the math problems. Each of these questions serves as a "guide" to show you what you should be thinking about when solving problems – because there are often many things you have to think about when solving math problems and it is very easy to forget something important. This strategy is most important when solving word problems."** The researcher should review each of the questions with the students before modeling the procedure to them.

Description of the 5 steps of the strategy

1) Determine key **Parts** of the Problem

Students should be encouraged to state in their own words what they think the problem is asking them to do. It is critical for students to be able to identify: (a) what is known and unknown in the problem; (b) relevant and irrelevant information; (c) does the problem involve more of or less than etc./ or increasing or decreasing; (d) what is being asked. Students should be encouraged to circle/underline the relevant information and cross out any irrelevant information. **However, they should not proceed to writing the numerical or mathematical equation until they follow step #2 and/or #3.

2) Draw a **Picture**

Addressing this step may not be required or desired depending on problem type. Certain math problems (word problems) are most amenable with drawing pictures, because they involve multiple parts and steps. The purpose of drawing pictures is to help students conceptualize the problem before they create the numerical problem in Step 4. Students can draw an actual picture representing key aspects of the problem.

3) Write out a numerical **Equation** (mathematical problem)
This step targets the translation of students' understanding of a problem and a picture into a numerical equation. Part of this question also involves identifying the correct sign. What is known or unknown? Check the validity of numerical representation.

4) Solve the Problem
This step involves performing basic computations as specified by the students in their number equation. This part also taps into students' knowledge of definitions of key terms as well as basic rules and procedures (e.g., order of operations; multiplying signs; rate of change).

5) Proofread and check answer
This final step involves reviewing and/or checking one's work. The students should be encouraged to retrace their steps to make sure their procedures made sense within the context of the problem and to double check any computations.

c) Modeling

The Researcher will model how to use this 5-step strategy when solving a math problem. The Researcher will use cognitive modeling procedures, such as "talk aloud" strategy, in order to communicate the process and logic behind executing the four problem-solving steps.

d) Guided Practice

The Researcher will give students the opportunity to practice with this problem-solving strategy when solving this math problem together. The Researcher will provide *prompts* (e.g., reminding them to look at the problem-solving card), *hints* (e.g., starting the procedures for solving a math problem but then having them complete it), and *feedback* (e.g., feedback about their use of the cue card, encouragement when having difficulty etc.) regarding students' progress and use of the strategy.

Primary Themes: (a) To teach students how to use the $\mathbf{P^3}$**-ESP** via direct explanation, cognitive modeling, and guided practice

Strategy Instruction Mathematics Problem: 1 Problem

Provide formula of Area = (length)(width)

1). The dimensions of a rectangular garden were 5m by 12m. Each dimension was increased by the same amount. The garden then had an area of 120m2. Find the dimensions of the new garden.

Instruct student in drawing diagram

Student's Answer:____________________

Correct Answer: width = 10m
length = 17m

c. **<u>Introduction of MPS practice session Task:</u>**

Say, **"Today we will be doing several math problems. While you work through the problems, I will stop you from time to time to ask you a few questions. I will read the questions to you, and all I need you to do is tell me what you think. There are no right or wrong answers to these interviews questions."**

Say, **"Before we begin to solve the problems, I will tell you the rules. You have as much time as you want to do these problems. How well you do on these problems will not affect your grade in math, but I want you to try your best."** **Sound good? / Okay? At any point, if there are any words that you do not understand or if you are unsure of a question meaning, please let me know and I can help you.**

☐ **Tear out and present the "First Math Problem preview" (next page)**

Math Problems Preview Page

First Math Problem Preview

1). The length of a rectangular room has a length that is 5 ft. greater than its width. The room has an area of 150 square feet. What are the length and width of the room?

Second Math Problem Preview

2). The length of a rectangle is 8 cm greater than its width. Find the dimensions of the rectangle if its area is 105 cm^2.

Third Math Problem Preview

3). The dimensions of a rectangular flower garden were 8m by 15m. Each dimension was increased by the same amount. The garden then had an area of $198m^2$. Find the dimensions of the new garden.

Microanalytic Protocol:

Section A: ***FORETHOUGHT PHASE* - First Iteration**

Interview Question #1a, 1b, and 1c:
Directions:

1. ☐ Say, **"Please take a look at this math problem (math problem #1). Do not start to do any math, but just read the problem and once you understand what the problem is asking, let me know."**
2. ☐ NOTE: If examinee begins describing the procedures that they will use:

   Say, "For right now, you don't have to tell me how to do the problems just yet. I just want you to read through the problems to get an idea of what they are asking for.

   ☐ Just after the participant reads the problems, but before s/he begins to solve the questions, Say: **"In a moment, I will have you begin solving these math problems, but first, I want you to answer a couple of questions**."

Interview Question #1a: Self-efficacy Question and Self-efficacy Cue Card.

Say, **"On a scale of 10 to 100 with 10 being not confident, 40 being somewhat confident, 70 being pretty confident, and 100 being very confident (show the cue card), how confident are you that you can correctly solve this math problem?"**

10—20—30—**40**—50—60—**70**—80—90—**100**

Not confident	Somewhat Confident	Pretty Confident	Very Confident

Interview Question #2a: Goal-Setting Question.

Say, **"Do you have a goal in mind as you prepare to practice these math problems? If so, what is it?"** Record answer here: ____

____

____

____

<u>Interview Question #3a: Strategic Planning Question.</u>
<u>Directions:</u>

1. ☐ Immediately after the student responds to interview question #2, administer interview question #3.

Say, "Do you have any plans for how to successfully complete these math problems?"

(Record response verbatim) ____

____

____

____

☐ **Tear out and present "First math Problem."**

1. ☐ Say: **Okay, now I want you to complete the problem. You can use the space here** (point to the blank space below the problem) **to do any math operations. If you need extra space to work, let me know because I have extra work paper. Please do not erase your work. If you decide to try a new approach to solving the problem, just cross out the old work like this** (show proper crossing out).
2. ☐ Provide the math problems one at a time.

<u>First Math Problem</u>

1). The length of a rectangular room has a length that is 5 ft. greater than its width. The room has an area of 150 square feet. What are the length and width of the room?

<u>Student's Answer:___________________</u>
Correct Answer: ____________
<u>*Make correct solution (outcome feedback) accessible for participants in all 3 conditions.</u>

<u>Directions:</u>

3. ☐ Administered the first math problem.

Provide Type of EXPF or SRPF

Experimental Condition – SRPF for Problem #1:

Directions:

B. Direct student to use the self-recording form for this condition:

1. Please write down your answer and compare it with the solution provided to you to see if it is correct or incorrect.

____

____

____

2. Please list the strategies and steps you used to solve this problem.

____

____

____

3. Complete the following two columns for the problem that you got incorrect. (SRL/process monitoring)

Why do you think you got this problem wrong?	**Check all that apply**	**What do you think are the most important ways for you to improve?**
1. I did not check my work		
2. I did not draw a diagram.		
3. I did not look at all possible choices		
4. I did not understand the problem		
5. I made a silly calculation mistake		
6. I missed one of the steps to solve the problem correctly		
7. Other (write out your answer)		
8. I did not show my work		

Experimental Condition – Verbal/EXPF for Problem #1:

B. Examiner will determine accuracy of Problem #1 and deliver the appropriate EXPF.

Directions: Script for EXPF.

If the problem is solved correctly, the researcher will present the problem to the student and state one of the following statements of EXPF:

- "you're learning to use the steps"
- "you're using the steps to solve the problems"
- "you're getting good at using the steps"
- "you're doing well because you followed the steps in order" (Schunk & Swartz, 1993)

If the problem is solved incorrectly, the researcher will present the incorrectly solved problem to the student, and provide EXPF by stating:

- "While you're working it helps to keep in mind what you're trying to do. Try to focus on using the steps to solve the problem" (Schunk & Swartz, 1993).
- "You need to follow the 5-step math strategy when solving these types of problems."

This EXPF refers to the strategy instruction at the start of the session and the researcher will point to the strategy steps on the Strategy Cue Card while delivering the feedback.
*******Strategy Cue Card will be made available to students in all conditions.*

Section B: ***PERFORMANCE PHASE* - First Iteration**

Interview Question #4a: Strategy Use Quesion.

Directions:

1. ☐ Administered interview question #4 immediately after the examinee finishes the first math problem and after receiving one of the two types of process feedback or only receiving the simple outcome feedback of the solution.

Say, **"Tell me all of the things that you did to solve this problem (**point @ problem #1)**."**

Record response verbatim____

____

____

____

If an answer is provided, prompt for a maximum of 2 prompts: **"Is there anything else that you did?"**

____

____

____

If an answer is provided, prompt: **"is there anything else that you did?"**

____

____

____

If multiple answers are given, Say: **"You said a few things that you did to solve the problem. What is the most important thing you did?"**____

____

Section A: ***FORETHOUGHT PHASE* - Second Iteration**

Interview Question #1b, 2b, 3b:
Directions:

3. ☐ Say, **"Please take a look at this math problem (math problem #2). Do not start to do any math, but just read the problem and once you understand what the problem is asking, let me know."**
4. ☐ NOTE: If examinee begins describing the procedures that they will use:

   Say, "For right now, you don't have to tell me how to do the problems just yet. I just want you to read through the problems to get an idea of what they are asking for.

   ☐ Just after the participant reads the problems, but before s/he begins to solve the questions, Say: **"In a moment, I will have you begin solving these math problems, but first, I want you to answer a couple of questions**."

Interview Question #1b: Self-efficacy Qustion and Self-efficacy Cue Card.

Say, **"On a scale of 10 to 100 with 10 being not confident, 40 being somewhat confident, 70 being pretty confident, and 100 being very confident (show the cue card), how confident are you that you can correctly solve this math problem?"**

10—20—30—**40**—50—60—**70**—80—90—**100**

Not confident	Somewhat Confident	Pretty Confident	Very Confident

Interview Question #2b: Goal-Setting Question.

Say, **"Do you have a goal in mind as you prepare to practice these math problems? If so, what is it?"** Record answer here: ______________________________

____

____

____

Interview Question #3b: Strategic Planning Question.
Directions:

2. ☐ Immediately after the student responds to interview question #2, administer interview question #3.

Say, "Do you have any plans for how to successfully complete these math problems?"

(Record response verbatim) ______________________________

____

____

____

☐ **Tear out and present "Second math problem."**

Second Math Problem

2). The length of a rectangle is 8 cm greater than its width. Find the dimensions of the rectangle if its area is 105 cm^2.

Student's Answer:___________________
Correct Answer: ____________
***Make correct solution (outcome feedback) accessible for participants in all 3 conditions.**

Experimental Condition – SRPF for Problem #2:

Directions:

B. Direct student to use the self-recording form for this condition:

1. Please write down your answer and compare it with the solution provided to you to see if it is correct or incorrect.

____

____

____

2. Please list the strategies and steps you used to solve this problem.

____

____

____

3. Complete the following two columns for the problem that you got incorrect. (SRL/process monitoring)

Why do you think you got this problem wrong?	**Check all that apply**	**What do you think are the most important ways for you to improve?**
1. I did not check my work		
2. I did not draw a diagram.		
3. I did not look at all possible choices		
4. I did not understand the problem		
5. I made a silly calculation mistake		
6. I missed one of the steps to solve the problem correctly		
7. Other (write out your answer)		
8. I did not show my work		

Experimental Condition – Verbal/EXPF for Problem #2:

B. Examiner will determine accuracy of problem #2 and deliver the appropriate EXPF.

Directions: Script for EXPF.

If the problem is solved correctly, the researcher will present the problem to the student and state one of the following statements of EXPF:

- "you're learning to use the steps"
- "you're using the steps to solve the problems"
- "you're getting good at using the steps"
- "you're doing well because you followed the steps in order" (Schunk & Swartz, 1993)

If the problem is solved incorrectly, the researcher will present the incorrectly solved problem to the student, and provide EXPF by stating:

- "While you're working it helps to keep in mind what you're trying to do. Try to focus on using the steps to solve the problem" (Schunk & Swartz, 1993).
- "You need to follow the 5-step math strategy when solving these types of problems."

This EXPF refers to the strategy instruction at the start of the session and the researcher will point to the strategy steps on the Strategy Cue Card while delivering the feedback.
***Strategy Cue Card will be made available to students in all conditions.*

2. ☐ Administered second math problem

<u>Section B: ***PERFORMANCE PHASE* - Second Iteration</u>**

<u>Interview Question #4b: Strategy Use Question.</u>

<u>Directions:</u>

1. ☐ Immediately after the examinee finishes math problem #2, administer question #4b.

Say, **"Tell me all of the things that you did to solve this problem (**point to math problem #2**)."**

Record response verbatim____

If an answer is provided, prompt: **"is there anything else that you did?"**

If an answer is provided, prompt: **"is there anything else that you did?"**

If multiple answers are given, Say: **"You said a few things that you did to solve the problem. What is the most important thing you did?"**

Section A: ***FORETHOUGHT PHASE* - Third Iteration**

Interview Question #1c, 2c, 3c:
Directions:

5. ☐ Say, **"Please take a look at this math problem (math problem #3). Do not start to do any math, but just read the problem and once you understand what the problem is asking, let me know."**
6. ☐ NOTE: If examinee begins describing the procedures that they will use:

   Say, "For right now, you don't have to tell me how to do the problems just yet. I just want you to read through the problems to get an idea of what they are asking for.

   ☐ Just after the participant reads the problems, but before s/he begins to solve the questions, Say: **"In a moment, I will have you begin solving these math problems, but first, I want you to answer a couple of questions**."

Interview Question #1c: Self-efficacy Question and Self-efficacy Cue Card.

Say, **"On a scale of 10 to 100 with 10 being not confident, 40 being somewhat confident, 70 being pretty confident, and 100 being very confident (show the cue card), how confident are you that you can correctly solve this math problem?"**

10—20—30—**40**—50—60—**70**—80—90—**100**

Not confident	Somewhat Confident	Pretty Confident	Very Confident

Interview Question #2c: Goal-Setting Question.

Say, **"Do you have a goal in mind as you prepare to practice these math problems? If so, what is it?"** Record answer here: ____

____

____

____

Interview Question #3c: Strategic Planning Question.
Directions:

3. ☐ Immediately after the student responds to interview question #2, administer interview question #3.

Say, "Do you have any plans for how to successfully complete these math problems?"

(Record response verbatim) ____

____

____

____

☐ **Tear out and present "Third math problem."**

<u>Third Math Problem</u>

3). The dimensions of a rectangular flower garden were 8m by 15m. Each dimension was increased by the same amount. The garden then had an area of $198m^2$. Find the dimensions of the new garden.

<u>Student's Answer:</u>___________________
Correct Answer: ____________
<u>*Make correct solution (outcome feedback) accessible for participants in all 3 conditions.</u>

Experimental Condition – SRPF for Problem #3:

Directions:

B. Direct student to use the self-recording form for this condition:
1. Please write down your answer and compare it with the solution provided to you to see if it is correct or incorrect.

____

____

____

2. Please list the strategies and steps you used to solve this problem.

____

____

____

3. Complete the following two columns for the problem that you got incorrect. (SRL/process monitoring)

Why do you think you got this problem wrong?	**Check all that apply**	**What do you think are the most important ways for you to improve?**
1. I did not check my work		
2. I did not draw a diagram.		
3. I did not look at all possible choices		
4. I did not understand the problem		
5. I made a silly calculation mistake		
6. I missed one of the steps to solve the problem correctly		
7. Other (write out your answer)		
8. I did not show my work		

Experimental Condition – Verbal/EXPF for Problem #3:

B. Examiner will determine accuracy of problem #3 and deliver the appropriate EXPF.

Directions: Script for EXPF.

If the problem is solved correctly, the researcher will present the problem to the student and state one of the following statements of EXPF:

- "you're learning to use the steps"
- "you're using the steps to solve the problems"
- "you're getting good at using the steps"
- "you're doing well because you followed the steps in order" (Schunk & Swartz, 1993)

If the problem is solved incorrectly, the researcher will present the incorrectly solved problem to the student, and provide EXPF by stating:

- "While you're working it helps to keep in mind what you're trying to do. Try to focus on using the steps to solve the problem" (Schunk & Swartz, 1993).
- "You need to follow the 5-step math strategy when solving these types of problems."

This EXPF refers to the strategy instruction at the start of the session and the researcher will point to the strategy steps on the Strategy Cue Card while delivering the feedback.
***Strategy Cue Card will be made available to students in all conditions.*

3. ☐ Administered third math problem

Section B: ***PERFORMANCE PHASE* - Third Iteration**

Interview Question #4c: Strategy Use Question.

Directions:

1. ☐ Immediately after the examinee finishes math problem #3, administer question #4c.

Say, **"Tell me all of the things that you did to solve this problem (**point to math problem #3**).”**

Record response verbatim____

____

____

____

If an answer is provided, prompt: **“is there anything else that you did?”**

____

____

____

____

If an answer is provided, prompt: **“is there anything else that you did?”**

____

____

____

If multiple answers are given, Say: **“You said a few things that you did to solve the problem. What is the most important thing you did?”**

____

☐ Say, “**That concludes the interview. Now, I will have you complete a few more math problems.”**

<u>Administer Posttest MPS.</u>

Problem #1.

1). The length of a rectangle is 7 m more than the width. The area is 30 m^2. Find the width and length.

Problem #2.

2). The length of a rectangular mural is 2 ft. more than three times the height. The area is 165 ft^2. Find the height of the mural.

Appendix F: SRL Microanalysis Coding Rubric

SRL Microanalysis Coding Rubric

Mathematical Problem Solving Edition

Developed By: Gregory Callan, Ph.D. and Timothy Cleary, Ph.D. (2014)

The Coding and Scoring rubric developed by Callan (2014) will be utilized in this dissertation to score the following three open-ended SRL questions: goal-setting, strategic planning, and strategy use.

Goal-Setting

Process Goals:

Definition: Statement indicates a focus on the execution of procedures or the processes involved in solving the math problem.

1. **Process Specific:**
   Definitions: Statements that focus on the process of solving the problem and also identify the use of a specific math strategy, tactic, or mathematical procedure as the primary focus of the problem solving session.
   - **1 point**
   - "I'll probably draw a picture to understand how to do these problems"
   - "I want to make sure that I identify the important information first, Etc.…
   - "I will do addition to find the perimeter."
     - Must say the procedure and how it will be used or for which problem it will be used.
   - "I will figure out what the problem is asking me"
   - "I will make sure that I really understand the problems"
   - "I will read the problem"
   - "I will highlight key information"
   - "I will make sure to draw a picture"
   - "I will write out an equation before I solve the problem"
   - "I will check to make sure that I did everything correctly when I am finished"
   - "I'll make an estimate of the correct answer before I do the computations"

2. **Process General:**
   Definition: Statements indicating a focus on a process in general but does not identify any particular procedures. **DO NOT** code **Process General** goals if the examinee has also indicated a **Process Specific** goal.
   - **1 point**
   - "Do it the right way"
   - "I want to choose the correct math for these problems."
   - "I want to do them fast"
   - "I will TRY my best"
   - "I will work hard"
   - "I'll give it my best"
   - "I'll think the problem through"
   - "try different methods"
   - "I need to understand the problem"

Outcome Goals:

Definition: Statement indicates a focus on achievement or an outcome during the problem solving session.

3. **Outcome Specific Goals or Outcome General Goals**

Outcome Specific Goals Definition: Statements that identify a clear and measureable outcome as the focus of problem solving practice session.
Outcome General Goals Definition: Statement identifies an outcome that is unclear, not quantifiable, or not directly measurable as the focus of problem solving practice session.

- **1 point**
- "I want to get 5 out of 5 of these problems correct"
- "I want to get 3 out of 5; 2 out of 5; etc.… of these problems correct"
- "I want to get all of these problems correct"
- "I want to get them ALL right"
- **Outcome general:** "I will DO my best"
- "I want get them DONE fast"
- "I want to do my best on these problems"
- "
- "I want to get better at doing math."
- "Get them right"
- "I want to get a lot/some of them right"

4. **Other Goal**
Definition: Statements that indicate a goal that does not fit into any of the other coding categories.
    - **1 Point**
    - Goals that are not reflected in the coding scheme and not incongruent with the task.
5. **Non-Task Goal**
Definition: Statements that indicate a goal that is so incongruent with the current task of the MPS practice session that the goal reflects an inadequate understanding of the task.
    - **1 Point**
    - "To get into college"
    - "To get a better math grade"
6. **No Goal**
Definition: Statement indicates that the student does not have a goal for the problem solving practice session.
    - **1 Points**
    - "no"
    - "I don't know"
    - "not really"
    - "I don't really have a goal"
    - Shakes head
    - Does not respond

The Math Problem Solving Strategy

General Coding Guidelines

NOTE: Use these general coding guidelines while coding responses for SRL Microanalytic questions that include the Math Problem Solving Strategy category (i.e., strategic planning and strategy use).

1. **Math Problem Solving Strategy (Total possible points= 15)**
   a) **Step 1 – Identify Key Information (Max points for category = 4)**
      Definition: Statements that describe tactics to identify the most pertinent information in the problem. Includes four categories: (1) Reading & Re-reading, (2) Search, (3) Highlight, Underline, or List, and (4) Identify the Problem.
      Coding Notes:
      "Identifying Key Information" **DOES NOT** include overt uses of the tactics themselves**.**
      - **(1) Read & Re-read (1)**
        Definition: Statements that describe reading or re-reading the math problem.
        - **+1 Points**
        - "I will read the problem"
        - "I will look over the problem"
        - "I will read it over a couple times"
        - "If I don't get it, I'll have to read it again".
      - **(2) Highlight, Underline, or List (1)**
        Definition: Statements that describe actions to isolate or identify the most pertinent information.
        - **+1 Points**
        - "I will underline/highlight the important information"
        - "I will write out the main information"
        - "I will eliminate information that is un-important"
        - "I will write out the positive and negative signs"
      - **(3) Search (1)**
        Definition: Statements of searching for key parts of the problem.
        - **+1 Points**
        - "I will search the problem for important information"
        - "I will look for key words"
        - "I will look for clues"
        - "I will search for the most important information/clues/hints"
        - "I'll make sure that I pay attention to each key word"
        - "I will look for the most important information"

        Non-Examples
        - Statements that describe the labeling of drawings or diagrams.
          - I wrote the length of each side down on the diagram that I drew (Code as translating - drawing).
        - Statements that describe pertinent information but does not specify the action of identifying that information.
          - "It says that there are 10 tables and that 4 people can sit at each one." (Do not code)
        - Statements identifying key information within the problem.

        - "well it says that there are 10 tables and 4 people can sit at each table"

- **(3) Identify the Problem/Question (1)**
  Definition: Statements that identify the necessity of identifying what the problem is asking them to do or what the problem requires.
        - **+1 Points**
    - **Directly references Problem Identification (1)**
        - "I need to understand/figure out what I am supposed to do"
        - "I need to figure out what the problem is asking me"

    Non-Examples
    - Statements that **Actually** Identify the Problem Type / Question
        - "This is a perimeter problem."
        - "This problem is asking me to add up all of the sides to find out how far the caterpillar walked."

b) **Step 2 – Translate (Max points for category = 3)**
Definition: Statements that describe the modification of the problem solving content changing the wording, formulating the problem into a visualization, or connecting the current problem content to a previous learning experience**.** **Translate** includes 3 categories: **(1)** Paraphrase, Re-state, **Or** Create an Analogous Problem, **(2)** Visualization, and **(3)** Elaboration.

Coding Notes:
"Translate" **DOES NOT** include overt uses of the tactics themselves**.**

- **(1) Paraphrase, Re-state, or Create an Analogous Problem (1)**
  Definition: Statements that describe actions such as re-writing, paraphrasing, or creation of analogous problems.
        - **+1 Points**
        - "I will make a simpler problem that is similar to this one"
        - "I will re-write the problem in my own words"
        - "I will summarize what the problem is asking me to do."

  Non-Examples:
    - Statements that actually paraphrase, re-state, or summarize the problem.

- **(2) Visualization (1)**
  Definition: Statements describing the use of pictures of mental images to aid problem comprehension or solution.
        - **+1 Points**
        - "I'll draw a picture"
        - "I'll make a diagram"
        - "I'll picture the path that the caterpillar travels in my head"
        - "I'll visualize the problem"

  Note: Statements that describe labeling graphics are coded as an instance of "visualization." Maximum of one instance of visualization per interviewee.

- **(3) Elaboration: (1)**
  Definition: Statements that describe the use of elaboration tactics wherein students connect the current task demands to prior learning experiences.
    - **+1 Points**
    - "I would use the 5 steps"
    - "I'll focus on the strategy instruction problem we did together"
    - "I'll think about past problems that I've done"
    - "I'll remember what the teacher taught us to solve the problem"

  Non-Examples
  - Statements that indicate engagement in reflection
    - "This is similar to a problem I've done before."
    - "I've done some like this before"
    - "Our teacher taught us a procedure for these types of problems"

c) **Step 3 – Hypothesize / Estimate / Predict the Answer (Max pts = 1)**
Definition: Statements that describe the creation of a hypothesis about a potential answer to the math problems.
  - **+1 Points**
  - "I will make a ball park guess of the right answer"
  - "I'll estimate what I think the answer should come out to"
  - I will guess and check

d) **Step 4 – Equation Development and Computation (Max pts = 3)**
Definition: Statements that explicitly reference the need to **(1)** develop an equation to solve the problem and **(2)** complete computations **OR** **(3)** statements that propose, select, or describe the completion of mathematical procedures or computations necessary to solve the problem.
  - **(1)** Equation Development Intention (1)
    - **+1 Points**
    - "I need to make an equation to solve this problem"
    - "Before I do the math, I will write out the equation"
  - **(2)** Computation Intention (1)
    - **+1 Points**
    - "Next I will need to solve the equation"
    - "Then I will compute the procedures that I selected"
  - Procedures Selection or Computation Completion (1)
    - **+1 Points**
    - "I'll do some addition for problem #4 to find the perimeter."
    - "I will add up 10, 10, 12, and 12 to find the perimeter of the garden."

- "Well, since 10, 10, 12, and 12 is 44. I know that the perimeter of the garden is 44 and then _____"
- "I added up the sides to find the perimeter"
- "I added 10 + 10 + 12 + 12 and then I multiplied it by two"

Non-Examples

- Statements that only list procedures or computations without identifying how or where they will be used.

e) **Step 5 – Check (Max points = 4)**
Definition: Statements that describe **(1)** the intention to monitor the understanding of the problem, **(2)** procedures to verify the accuracy or appropriateness of one's work, or **(3)** to compare their solution to an estimated answer.

- **(1) Check / Monitor Understanding (2)**
  Definition: Statements that describe tactics to check / monitor the understanding of the problem. These statements may describe **(A)** the intention to use specific strategies to monitor understanding (e.g., self-questioning) or **(B)** may make direct references to monitoring understanding.
  - **(A) Self-Questioning (1)**
    Definition: Examinee indicates that they will ask themselves questions about the current task demands.
    - **+1 Points**
    - "I will ask myself questions about the problem as I do it"
    - "I will prompt myself to make sure that I am doing the right things"
  - **(B) Direct References Checking Understanding (1)**
    Definition: Statements that describe the intention to check understanding
    - **+1 Points**
    - "I will make sure that I am understanding the problem"

  Non-Examples of "Checking / Monitoring Understanding
  - Indicators of Monitoring of Understanding
    Definition: Statements which are only possible if one has monitored their understanding. For example, in order to identify one's current understanding (e.g., I don't really get this one) it is necessary that they engaged in monitoring behaviors.
    - "I got confused by this one…."
    - "I'm not really understanding this one yet…"
    - "I get this one"

- **(2) Check Performance (1)**
  Definition: Statements that describe the checking of operations for accuracy and appropriateness

    - **+1 Points**
    - "I'll check if I selected the right operations"
    - "I will check my work"
    - "I'll make sure that I did the computations right"
    - "I'll double check my work"
    - "I'll make sure I didn't make any errors"
- **(3) Compare Solution and Estimate (1)**
  Definition: Statements that describe checking the solution to determine if it makes sense.
    - **+1 Points**
    - "I will compare the answer I got with my estimate"
    - "I will see if the answer makes sense"

Strategic Planning
Coding Guidelines

1. **Math Problem Solving Strategy (Total possible points= 15)**
Follow the MPS general coding guidelines listed above.

**********************NON-MPS Coding Categories (4) ************************

2. **Other**
Definition: Statements that identify a specific behavior or strategy that is not found or better coded as another category. Could include other SRL strategies such as self-control.
    - **1 Points**
    - "I will make sure that I don't rush" **or** "I'll take my time"
    - "I will take a deep breath before starting the problems to calm my nerves"
    - "I will visualize myself succeeding on these problems"
    - "I will tell myself to keep trying even if the problems are really hard"
    - "I will keep reminding myself that I need to: (describes specific math procedures)"

    Notes: Other responses are **NOT** coded if examinee provides an answer that can be coded into one of the other identified categories. RECORD the response that is being identified as "OTHER" in the coding spread sheet for later examination.
    - Examples are likely to be low incidence statements"

3. **Non-Task Plans**
Definition: Statements that indicate a goal that is so incongruent with the current task of the MPS practice session that the goal reflects an inadequate understanding of the task.
    - **1 Points**
    - "I would probably ask my teacher for help"
    - "I will probably look in my notes to figure out how to do these problems"
    - "I would probably use a calculator."

4. **Don't Know or No plan**
Definition: Statements that indicate that the examinee does not know how to approach the problems or what they will do to solve the problems.
Notes: Statements are **NOT CODED AS DK** if the statement is followed or preceded by a different code-able response.
    - **1 Points**
    - "I have no idea"
    - "don't know"
    - shakes head / provides no response
    - "I'm not sure"

Strategy Use
Coding Guidelines

1. **Math Problem Solving Strategy (Total possible points= 15)**
   Follow the MPS general coding guidelines listed above.

*********************** **NON-MPS Coding Categories (3)** *************************

2. **Other**
   Definition: Statements that identify a specific behavior or strategy that is not found or better Coded as another category.
   Note: **Other** responses are **NOT** coded if the examinee provides an answer that can be coded into one of the other identified categories. RECORD the response that is being identified as "OTHER" in the coding spread sheet for later examination.
   - **1 Points**
   - Examples are likely to be low incidence responses
3. **Non-Task Strategies**
   Definition: Statements that indicate a goal that is so incongruent with the current task of the MPS practice session that the strategy reflects an inadequate understanding of the task.
   - **1 Points**
4. **Don't Know or No Strategy**
   Definition: Statements that indicate that the examinee did not use a strategy or cannot explain how they solved the problem.
   Note: These statements are **NOT CODED** AS DK/NO if the statement is followed or preceded by a different code-able response.
   - **1 Points**
   - "I don't know"
   - "not sure"
   - "No response provided"

Microanalysis Scoring Template						
Goal Setting Microanalytic Question Scoring						
Scoring	+1	+1	+1	+1	+1 pt	+1pts
CRITERIA	Process Specific	Process General	Outcome	Other goal	+1 point for **'non-task'** goals that are inconsistent **ONLY if** no other goal type is code-able.	+1 points for **'IDK'** goals or **'No' ONLY if** no other goal type was provided

Strategic Planning Microanalytic Question Scoring and Strategy Use Microanalytic Question Scoring	
Scoring Criteria	Possible points for MPS strategy components (max 15 pts)
Identify Key information (Max= 4pts)	1. Read 2. Highlight, underline, list, 3. Search Identify the question
Translate (Max= 3pts)	1. Paraphrase 2. Visualize Elaborate
Hypothesize / Estimate (Max= 1pt)	
Equation Develop (Max= 2pt)	1. Computation 2. Procedures Selection
Check (Max= 4pts)	1. Check understanding a. Self-Question b. Direct references 2. Check performance Compare solution & estimate
I don't know; No plan	+1 point for plans that indicated plans that are inconsistent **ONLY if** no other plan is code-able. Plus 1 points for **'IDK'** or **'No'** plan **ONLY if** no other plan type was provided.

Appendix G: Mathematics Problem-Solving Answer Key and Coding Rubric
Adapted from Callan (2014)

General Coding Guidelines:

- Use same coding steps for all problems. (3 problems administered during the practice session and 2 posttest math problems administered to students after SRL practice session).
- Adapted Callan's (2014) rubric for the types of math problems we created for this dissertation. Callan (2014) broke each problem down to 3 criteria. Similarly, we will grade each of these 3 steps independently, so a student can get credit for step 2 if the student did that portion correctly, even if they didn't get credit for step 1. Thus, if a student did not complete step 1 correctly it is still possible to get credit for later steps.
- Half-Credit – handled similarly to Callan (2014) as well.
    - Rationale: Callan (2014) also allowed students to receive half credit for each step if the operations were selected correctly but the results were incorrect due to minor calculation errors. We will still allow students to receive half credit for steps that they knew what operations to select, though they may have incorrectly completed the operations. We will keep this criteria because Callan (2014) found that selecting the right procedures but calculating incorrectly (giving students half-credit) was more adaptive than students who selected incorrect procedures (for which students receive no credit). Therefore this piece will remain consistent with Callan's (2014) work in that students can receive partial credit for "selecting the right procedures but calculating incorrectly."
- No credit for just trying something: Callan (2014) allowed students to gain points if they showed evidence of an attempt. This dissertation focuses on SRL and strategies during math practice, so we should not award points only for attempting something as opposed to skipping the problem. Therefore if a student just writes down anything, they will not receive points unless it falls into one of the steps. Differs from Callan's (2014) work as students cannot receive partial credit for "attempting something as opposed to completely skipping the problem."
- Due to Callan's (2014) recommendation, this Coding schema was adapted from Callan's (2014) work with the help of a content expert to make sure the steps fit the problems. The primary researcher worked with a high school math teacher from the target high school to break the coding steps into 3 steps similar to Callan's (2014).

Overall Notes for Math Problem Scoring Partial or Zero Credit:

- Partial Credit can be obtained:
    - Student chose correct operation but did minor calculation error – .5 points
    - Ex. Student chose correct steps such as to factor or FOIL, but made error.
- Can skip steps – if student gets step 1 wrong, can still get points for step 2.
- Point system – Callan (2014) gave each criteria value of 2.5 points, we are going to stay consistent with our binary code scoring like in SRL, and give 1 point or .5 (if partial credit because calculation error)
- No points given for just an attempt.
    - Score as a 0 if just attempted and doesn't fit into any of the Steps or fit into Partial

Credit category
- Score as 0 if shows no work.

Scoring is based on 3 Steps. Students can earn up to 3 points for each Math Problem.
Follow this scoring for **Math Practice Problems 1 – 3 and Posttest Problems 1 – 2.**

1. **Step 1**: **Equation** (+1 point)
   a. Definition: Student Identified the correct equation of Area = (length)(width).
   b. Gain the point for this step irrelevant of whether student decided to draw a picture or no picture.
   c. Example of gaining a point for Step 1:
      i. Decided that "w" represents width and length is l = w +5, so make equation of A=w(w+5)
   d. **Half Credit (.5)**: if student indicates that they know it must follow formula A=(l)(w) but does not translate the formula into the correct equation specific to this problem.
   e. **No Credit**: if creates wrong equation
2. **Step 2: Solving Equation for Variable** (+1 point) (or .5 points if chose correct steps, FOIL out the problem, attempt to factor, but made simple calculation errors)
   a. Definition: Student correctly solves the equation to find the value of "w".
   b. Solved the equation correctly, this includes multiplying, factoring, order of operations (FOIL), adding/subtracting
   c. Identified correct value of the variable in their equation.
      i. Choosing correct procedures and choosing which value of w was correct, sometimes needing to eliminate/reject the negative value, or other possible values that are incorrect.
   d. **Half Credit (.5):** If selected the correct operation (i.e., to factor), but did calculations wrong. Because the student chose correct procedure it is thought this is more adaptive than selecting incorrect procedures.
   e. **No Credit** given – when student chooses incorrect procedures.
3. **Step 3: Finding Length and Width** (+1 point)
   a. Definition: Student knew they needed to plug in this value back into equation in order to gain 2 values to actually answer the question– value for width, value for length. Correctly finds the values for length and width.
   b. Example of gaining +1 for Step 3:
      i. Ends problem #1 with w=10 and l=15
      ii. Student plugged in values correctly to gain answer of width and length.
      iii. Remembered that needs these values to actually answer question
   c. **Half credit (.5)**: student chooses correct procedures to try to find width and length (plugs in the variable value back into equation to find these values) but does simple calculation error.
   d. **Zero credit:** Student does not do correct operations to find length and width, or does not try to find length and width values at all.

Note: Use the Below calculations to check calculations for each problem and selected procedures, to ensure that student is doing calculations for the problems accurately.

<u>**Mathematics Practice Session : 3 Problems**</u>
<u>**First Math Problem**</u>

1). The length of a rectangular room has a length that is 5 ft. greater than its width. The room has an area of 150 square feet. What are the length and width of the room?

***draw diagram**

Solution: width = 10ft
length = 15ft
Work:
A = (length)(width)
A = (w + 5)w
A = w^2 + 5w
150 = w^2 + 5w
0 = w^2 + 5w – 150
0 = (w + 15)(w – 10)
w = -15, 10
Reject -15 because it does not match problem
w = 10ft
l = 10 + 5 = 15

<u>**Second Math Problem**</u>

2). The length of a rectangle is 8 cm greater than its width. Find the dimensions of the rectangle if its area is 105 cm^2.

***draw diagram**

Solution: width = 7cm
length = 15cm
Work:
A=l(w)
105 = (8 + w)w
105 = w^2 + 8w
0 = w^2 + 8w – 105
0 = (w + 15)(w – 7)
w = -15, 7
Reject -15 because it does not match problem
w = 7cm
l = 8 + 7 = 15cm

Third Math Problem

3). The dimensions of a rectangular flower garden were 8m by 15m. Each dimension was increased by the same amount. The garden then had an area of $198m^2$. Find the dimensions of the new garden.

***draw diagram**

Solution: width = 11m
length = 18m
Work:
Length = x + 15
Width = x + 8
A = (x + 8)(x + 15)
$198 = x^2 + 15x + 8x + 120$
$198 = x^2 + 23x + 120$
$0 = x^2 + 23x - 78$
0 = (x + 26)(x – 3)
x = -26, 3
Reject -26 because does not match problem
x = 3

Posttest Mathematics Problems: 2 Problems
Posttest Problem #1.

1). The length of a rectangle is 7 m more than the width. The area is 30 m^2. Find the width and length.
***draw diagram**

Solution: width = 3m
length = 10m
Work:
A = w(w+7)
$30 = w^2 + 7w$
$0 = w^2 + 7w - 30$
0 = (w + 10) (w – 3)
w = -10, 3
Reject -10 as it does not match problem
w = 3
length = 7 + 3 = 10

Posttest Problem #2.

2). The length of a rectangular mural is 2 ft. more than three times the height. The area is 165 ft^2. Find the height of the mural.

***draw diagram**

Solution: width/height = 7.09 (7.1)
length = 23.27
Work:
165 = h(2 + 3h)
165 = $3h^2$ + 2h
0 = $3h^2$ + 2h – 165
0 = 3(h + 5)(h – 7.09)
h = -5, 7.09
Reject -5 as does not fit problem
h = 7.09
l = 2 + 3h = 1 + 3(7.09 = 23.27

<u>**Strategy Instruction Mathematics Problems: 1 Problem**</u> (No Scoring needed, Instruction completed with all students during strategy instruction time)

Provide formula of Area = (length)(width)

1). The dimensions of a rectangular garden were 5m by 12m. Each dimension was increased by the same amount. The garden then had an area of 120m2. Find the dimensions of the new garden.

***draw diagram**

Solution: width = 10m
length = 17m
Work:
(x + 12)(x + 5) = 120
x2 + 5x + 12x + 10 = 120
x2 + 17x – 110 = 0
(x – 5)(x + 22) = 0
x = 5, -22
Reject -22 as does not match problem
w = x + 5
l = x + 12