Scaffolding the Development of Self-Regulated Learning in Mathematics Classrooms

Results from an action research study examine the development of self-regulated learning behaviors in a seventh grade mathematics class.

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Educators today are being challenged to think beyond simple, skills-based conceptions of teaching and learning and to support young learners' thinking and reasoning. The National Council of Teachers of Mathematics (NCTM), the National Research Council (NCR), and the National Governors Association Center for Best Practices (NGAC) and Council of Chief State School Officers (CCSSO) have called for approaches to teaching and learning mathematics that deeply engage students in mathematical processes to develop mathematical proficiency (NCTM, 2000; Kilpatrick et al., 2001; NGAC-CCSSO, 2010). These calls to action highlight the need to develop classroom environments and specific instructional strategies that support learning content while also developing strategic learning behaviors. Typically, early mathematics instruction has consisted of helping students learn basic mathematical facts, carry out the steps of an algorithm, or understand mathematical concepts. This article provides another perspective on instruction based on broadening definitions of mathematics and mathematical competence, theories of self-regulated learning (SRL), and theories of social interaction within classrooms that support students' development of regulatory skills and strategies.

In every classroom there are learners who are more independent than their classmates. These students are eager to begin working and often plan how to accomplish assigned tasks. Researchers have coined the term *self-regulated learner* to depict the proactive nature of such students' approaches to learning (Zimmerman, 1990). Too often, however, we fail to cultivate these competencies in each and every student. Emphasizing short-term mastery goals without attending to students' development of strategic learning skills can adversely affect what students think about their own ability to develop understanding and what it means to learn, ultimately limiting their competence as problem solvers and self-regulated learners.

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As students enter the middle grades, more is expected of them in terms of taking responsibility for academic growth. This increased expectation may be particularly evident as students are asked to complete homework assignments in several distinct subject areas and study independently for tests. Some students have difficulty moving from the comprehensive social support that was provided in elementary school environments, where most classes are self-contained, to the environment of middle school, where students move between rooms to separate subject area classes taught in pre-determined time segments by different teachers. To be successful in the middle grades and beyond, students must learn to navigate these new demands. Teachers play an important role in providing developmentally responsive instruction to help students acquire the knowledge, skills, and dispositions necessary for success.

As middle school educators strive to provide developmentally responsive instruction for young adolescents, they must be "providing all students with the knowledge and skills needed to take control of their lives" (National Middle School Association, 2010, p. 14). Although our work took place in a mathematics classroom, scaffolding the development of regulatory strategies and skills is necessary in all content areas. Young adolescents want to feel competent and responsible for themselves. However, they may not be aware of ways to evaluate their own learning behaviors, to make plans for modifying those behaviors, and then to act on plans to improve learning, thus increasing feelings of competence and responsibility. Teachers must help students become more aware of these cyclical processes—forethought, performance, and reflection—so that they will be able to attribute their successes, and possibly failures, to their own decisions and actions.

In this article, we provide a theoretical framework for SRL and mathematics education that has potential for impacting the ways students learn. We then present action research, which occurred over the course of one school year, designed to support the development of problem-solving skills and SRL through guided instruction. The critical features of our work with seventh grade mathematics students include use of a strategy observation tool and reflective classroom discourse on strategic behaviors.

Literature review

Self-regulated learning

Self-regulated learners are cognitively active in their own learning. According to social cognitive theory, there are three phases of self-regulation: forethought, performance, and self-reflection (Zimmerman, 1994, 1998, 2000). Prior to beginning a learning task (forethought), self-regulated learners analyze the task to determine the steps they need to accomplish the task. They set goals for their learning, such as how much they will accomplish each day to get ready for an upcoming test or class project, and search their repertoire of strategies or skills for an appropriate way to accomplish the task. While studying for a test or completing a set of mathematics problems (performance), they monitor their progress toward understanding. After they have worked for a while, self-regulated learners assess their progress in accomplishing their goals (self-reflection) and may alter their subsequent behaviors, depending upon feelings of success (they cycle around to forethought that may result in performance control, etc.). Self-regulated learners have the knowledge, skills, and dispositions to accomplish academic goals they set for themselves.

Schunk and Zimmerman (1997) identify four levels of academic competence in the development of SRL: observational, imitative, self-controlled, and self-regulated. Progression through the developmental levels can be facilitated through structural scaffolding of effective ways of learning (Schunk & Zimmerman, 1997; Zimmerman, 2000). Students must first view a model performing a strategy (observational level). Classroom teachers can provide these models by making their thinking explicit for their students, by guiding their students in *how* to learn as well as what to learn, and by asking students to share the ways they go about learning. Later, students need to emulate these strategies and skills (imitative level), perhaps during practice sessions following discussions of how to study for a test. Within structured circumstances in which feedback related to their efforts is provided, students begin to perform the skills independently (self-controlled level) and, ultimately, gain the ability to adapt these skills to varying conditions (self-regulated level).

SRL strategy use has been related to and predictive of academic achievement and problem-solving success (Pape, 2004; Pape & Wang, 2003; Zimmerman & Martinez-Pons, 1990). Furthermore, students' perceptions of self-efficacy, such as their judgment of their capability to do mathematics, are impacted by their strategic efforts and are predictive of future strategy use (Pajares & Miller, 1994; Schunk, 1991; Zimmerman, Bandura, & Martinez-Pons, 1992; Zimmerman & Martinez-Pons, 1990). Students who exert strategic effort to learn may find success in their strategies. Small successes bolster students' self-efficacy (Schunk, 1991; Zimmerman et al., 1992), and when students attribute their success to the use of strategies, they are more likely to continue to use these strategies (Borkowski, Weyhing, & Carr, 1988; Borkowski, Weyhing, & Turner, 1986).

Social constructivist perspectives of teaching and learning have also informed our understanding of the development of SRL in classroom contexts. From a social constructivist perspective, the development of self-regulation begins with interactions between individuals (Bronson, 2000; Diaz, Neal, & Amaya-Williams, 1990; Wertsch & Stone, 1985). For example, an adult in a child's environment initially mediates and supports the child's efforts to carry out a task or behavior such as using a strategy. The child gradually takes on the responsibility of accomplishing the task or behavior that was first co-regulated with the adult. The child's ability to carry out the behavior gradually evolves from co-regulation to self-control and then self-regulation (Diaz et al., 1990; McCaslin & Hickey, 2001). The behaviors learned, the goals set, and the motivations to attain these goals are determined within and by the child's social surrounding, such as the classroom context, and are passed on through social interactions (Bronson, 2000; Ellis, 1997).

These theoretical perspectives have important implications for thinking about classroom instruction. They offer an outline of the structures and processes of SRL behavior and focus attention on the crucial nature of the teacher and the social context of the classroom in supporting the development of self-regulation through co-regulatory practices. Thus, they provide a focus for teaching and learning that moves beyond the mere development of content knowledge toward a view of supporting growing learners—addressing "both academic and personal development of every young adolescent" (NMSA, 2010, p. 4).

Mathematics education and SRL

Within the past 20 years, the view of mathematics as a body of facts students were to memorize and recapitulate has changed dramatically, largely as a result of three factors: (a) international comparative studies (e.g., Gonzalez, Williams, Jocelyn, Roey, Kastberg, & Brenwald, 2008; National Research Council, 1996; Sherman, Honegger, & McGivern, 2003), (b) the standards movement in mathematics education (NCTM, 2000; NGAC-CCSSO, 2010), and (c) pressure from increased globalization and technological work environment (English, 2002). The current view of mathematics as *a way of thinking* that requires justification and reasoning necessarily changes the definition of what it means to learn and succeed within the domain. New goals emphasizing conceptual understanding, strategic competence, adaptive reasoning, productive dispositions, and procedural fluency (Kilpatrick et al., 2001) require that teachers attend to students' regulation of academic behaviors. While these goals for mathematics education are widely embraced by educators, designing classroom environments and instructional practices designed to support the development of these competencies in young adolescents are still the exception (Hiebert et al., 2003).

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Contemporary views of mathematics education call for teaching of both content and processes associated with performance and knowledge of mathematics. The NCTM (2000) *Principles and Standards for School Mathematics* delineated five process standards (problem solving, reasoning and proof, communication, connections, and representation) for school mathematics programs. More recently, NGAC-CCSSO (2010) has identified eight mathematical practices that should be incorporated into mathematics instruction: making sense of problems and persevering in solving them, reasoning abstractly and quantitatively, constructing viable arguments and critiquing the reasoning of others, modeling with mathematics, using appropriate tools strategically, attending to precision, looking for and making use of structure, and looking for and expressing regularity in repeated reasoning.

These mathematical processes and practices may be thought of as both *processes* for learning mathematics and *outcomes* of that learning. For example, students learn mathematical content through communication, such as explaining and justifying their responses (Cobb, Wood, & Yackel, 1993; Yackel & Cobb, 1996; Wood, 1999), and they learn to communicate mathematically as they engage with the content. Similarly, by representing mathematical relationships, students learn content such as data analysis or rate of change, and an outcome of learning such content is the ability to represent mathematical relationships or to use mathematics to understand real-world situations. By incorporating these processes and practices into middle grades mathematics, teachers support development of thinking processes necessary for young adolescents to become self-regulated learners.

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An example self-regulation intervention

Cleary and Zimmerman (2004) described a school-based intervention, the self-regulation empowerment program (SREP), which incorporates a problem-solving model from cognitive psychology with the cyclical model of SRL. The intention of the intervention is to involve the students in the process of regulating their behaviors toward accomplishing academic tasks. Students are guided "to develop a strategic plan for attaining self-set goals (i.e., forethought processes), to implement study strategies and monitor performance processes and outcomes (i.e., performance control processes), and to evaluate strategy effectiveness and to make strategic adjustments as needed (i.e., self-reflection processes)" (Cleary & Zimmerman, p. 540). Diagnostic assessment included analysis of data from report cards, prior test results, self-reports of strategy use, teacher interviews, and think-alouds. Students were interviewed with a series of questions such as: "Do you have a goal when studying for your math tests?" "What do you do when you don't feel like studying for your math test?" (p. 543).

Intervention occurred in several phases. First, a coach (e.g., a school counselor or school psychologist) helped the students to self-observe the strategies they were using and to make the connection between these strategies and their outcomes, which were graphed to make the patterns in the outcomes more salient. This was done to help students cultivate the belief that they were in control of their academic outcomes. Second, the coach provided instruction to alter patterns of inefficient strategy use by modeling strategies, providing hints and feedback on the use of the strategies, and engaging students in guided practice sessions. Third, the cyclical feedback loop was emphasized. Accordingly, students were taught to set goals, to select strategies for accomplishing these goals, to observe and monitor their strategy use, and to make adjustments when necessary. A crucial step in monitoring their strategy use was graphing the outcomes of their behaviors, which helped the students attribute successes to effective strategy use and failures to less effective use of strategies. Cleary and Zimmerman (2004) reported that the intervention supported (with some limitations) the development of SRL behaviors within this relatively small-scale project.

Summary

Contemporary conceptions of teaching and learning (e.g., AMLE, 2010; NCTM, 2000; Kilpatrick et al., 2001; NGAC-CCSSO, 2010) suggest teachers must support learning beyond subject-specific content knowledge. Teachers can encourage students to engage in strategic self-regulating behaviors (i.e., forethought, performance control, and self-reflection) and provide instructional support at appropriate levels of development (i.e., observational, imitative, self-controlled, and self-regulated) (Zimmerman, 2000) to foster the development of SRL. Instruction and intervention may occur through modeling of SRL behaviors and providing feedback to students, such as coaching in observations of behavior, suggestions for strategic action, and guided practice (Cleary & Zimmerman, 2004). Although these ideas could be applied to any school subject area, the literature described above informed our conceptions of teaching and learning mathematics and supporting the development of SRL with seventh grade students.

Scaffolding SRL in a seventh grade classroom

To deepen our understanding of how to create a supportive classroom context for the development of SRL, we worked in an urban setting with seventh grade students in a mathematics class for one school year (Pape, Bell, & Yetkin, 2003). Several classroom sessions were video recorded throughout the year. An observer took notes during the video recorded class sessions, and notes were kept during weekly planning sessions, in which we reflected on teaching practices and student learning. Additional data came from students' strategy observations (*Strategy Observation Tool* and graphs) and journals.

The authors met weekly as needed to design learning experiences focused on strategies middle grades students use in academic settings that would support their developing sense of agency and skill in developing responsibility for their learning. Our goal was to incorporate the cognitive processes and developmental stages of SRL described above. For example, problem-solving tasks were used to guide students through processes similar in form to the cycle of self-regulated learning (De Corte, Verschaffel, & Op't Eynde, 2000; Pape, Bell, & Yetkin-Ozdemir, 2012). The tasks, which related to school district standards for seventh grade mathematics, were selected from several offered as possibilities in a curriculum guide or were created to address the standards. Many activities suggested in the curriculum guide were easily adaptable for our goal of supporting the development of SRL.

A critical element of planning was the deliberate attempt to make SRL processes a standard feature of learning mathematics: As students approached a task, they were given time to explore and make sense of the problem and then discuss ideas and form plans for carrying out the task in small groups (forethought).

Figure 1 Strategy Observation Tool. This figure illustrates the way a student might have used this form over the course of one week.

	In Class	**At Home**
Monday	Assembly	No homework. I didn't study.
Tuesday	I worked on The Johnson Family Trip with my table group. We shared ideas on how to make a graph.	I did my homework on multi-step equations.
Wednesday	I worked in my table group with rectangles to find the area as a model of the distributive property.	Practice sheet—multi-step equations
Thursday	We reviewed solving equations for the quiz. Quiz on multi-step equations.	No homework!
Friday	I made a design with equations that have x squared. Mine looked different from all the rest.	I told my parents about the graphing calculator designs.
Weekend		No homework!

Strategy Used		**Reasons for Results**	**Potential Strategies/Modifications**
I did all my homework and paid attention in class.	Rating 8	My score wasn't as good as I thought. I need to be better at remembering what I should do.	I can try to make a practice quiz for myself before the real quiz.
	Confidence +1		
	Self-Efficacy 9		
	Quiz Score 7		

After acting on the plans, the class would break from small-group work to engage in whole-class discussion of students' progress (performance control). Students were then encouraged to modify their approaches to the task, as needed, based on strategies shared during discussion. Students observed peers' models of strategic problem-solving behavior (observation), tried the new strategies (imitation and performance control), and examined their effectiveness (self-reflection).

The strategy observation tool

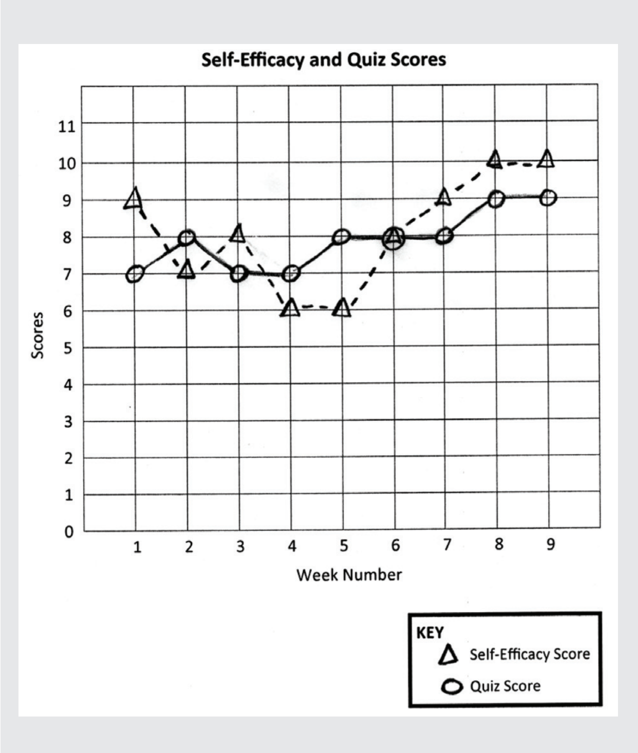
One noteworthy feature of our work involved our creation and use of a graphic organizer for recording strategic behavior. The *Strategy Observation Tool* highlighted the cyclical nature of self-regulation, as related to daily activities and weekly quizzes (see Figure 1). The intent was to help students realize connections between the actions they take to learn, teachers' assessments of their academic performances (quiz scores), and self-efficacy. We defined self-efficacy as an individual's judgment about their ability to perform well on a quiz. To rate self-efficacy, students combined their predictions of how they would score on a quiz (using a 10-point scale) with their feelings of confidence in their prediction (-1 for low confidence, 0 for neutral, or +1 for high confidence). Students were encouraged to record how they studied during the week. Following each weekly quiz, students were asked to record and graph self-efficacy and quiz scores and make plans for future study (see Figures 1 and 2).

The goal for tracking study strategies and quiz scores was to encourage students to attribute learning outcomes (quiz results) to their strategic behaviors. A few students were able to make an attribution for the first time. For example, one student said, "This is the best test score so far because this is the first time I really worked hard and worked with my mom for studying."

During the first two months of using the *Strategy Observation Tool*, some students wrote about taking notes, paying attention, asking questions, doing homework, showing parents their work, and reviewing materials. While these behaviors were not described as explicitly as we would have liked, these students were providing evidence of thinking about study behaviors. However, many students, had difficulty articulating their study strategies and reflecting on the connection between their study behaviors throughout the week and their quiz scores. The form did not explicitly call for writing about strategic behavior on a daily basis, and many students simply recorded assignments. We hypothesized that more explicit discussion of strategic behavior and less time between students' planned strategic study and feedback on academic performance might be more effective in helping students—especially those who struggled academically—understand connections between study behaviors and performance, thus helping them attribute their scores to their actions. Accordingly, the *Strategy Observation Tool* was modified to focus students' attention on the study strategies they used immediately prior to a quiz and their subsequent performance on the quiz (see Figure 3).

On the day before a quiz, students recorded the strategies they planned to use to study (forethought). Whole-class discussion of their plans allowed them to share their ideas and possibly adopt strategies suggested by others. They then monitored and recorded the ways in which they prepared for the quiz (self-observation; performance control). Following the quiz, they reflected on the relationship between their study strategies and the quiz results (self-reflection) and made plans for

Figure 2 Graph of self-efficacy and quiz scores illustrating the weekly scores of one student over a 9-week grading period.



what they might try the following week (self-reflection; forethought). In addition to using the *Strategy Observation Tool*, students were asked to graph their self-efficacy and quiz scores (see Figure 2). The graphs, which were kept for nine-week grading periods, not only helped students see patterns in their self-efficacy as related to quiz scores but also provided a real-life application of collecting and analyzing data.

Reflective classroom discourse

Reflective classroom discourse was another major feature of scaffolding the development of SRL during mathematics class (see Cobb, Bouffi, McClain, & Whitenack, 1997). Throughout activities and discussions, students were pressed to talk about thinking processes and about making sense of the mathematics—finding "correct" numerical answers was de-emphasized. Students were encouraged to explain strategic thinking before providing answers to problems (Pape et al., 2003). These discussions are illustrated in the following classroom excerpt.

Teacher 1: What did you have to think about? What strategies did you use ... to be comfortable with the new material?

Student 1: To unsquare 150 ... I made three guesses. I knew 12 was too low, so I began with 13.

Teacher 1: Did he use a strategy?

Student 2: Guess and check.

Teacher 1: Did he use another strategy?

Figure 3 Strategy Observation Tool—revised. The "filled in" form illustrates how a student might use this tool.

WEDNESDAY

Tomorrow there will be a quiz on: **Solving multi-step equations**

This is how I will study for the quiz: **I am going to do some practice problems and then explain what I did to my dad**.

Score I think I will earn on the quiz (0 to 10): 8 (A)

My confidence level (-1, 0, +1): +1 (B)

Self-Efficacy rating (add two values above): 9 (A + B)

FRIDAY

This is what I did to prepare for the quiz I took yesterday:
I did 6 practice problems for review. My dad wasn't home, so I explained them to my sister. She showed me another way to get the same answers.

This is the score I earned: 10

Questions to guide reflection:
How does the score you earned on the quiz compared to what you predicted on Wednesday? If it is very different, why is it different? (What are the reasons that you did not receive the score you thought you would?)
I did better on the quiz than what I thought. I did better because I explained my work this time, and that made me have to really remember.

What can you do differently to improve your score next week?
I can't improve my score, but I am going to review the same way so I can get 10 again.

Student 3: Process of elimination, because he first thought about 12 and knew that was too low, so he tried 13.

Student 4: [I] moved on.

Teacher 1: Moved on? Is that a strategy? Explain...

Student 5: When you move on, if you have [another] idea, it will sort of clear your mind. (pp. 190–191)

> Students came to understand that they could analyze their learning behaviors and learn from each other's experiences as well.

The questions driving this dialogue prompted the students to think about their problem-solving methods and move beyond simple question and answer exchanges or procedural explanations. Through our coaching and participation in classroom discussions, students were supported to focus on strategies for learning. They shared their experiences, which were then open for discussion by the whole class. Students came to understand that they could analyze their learning behaviors and learn from each other's experiences as well.

The importance of understanding *what it means to study* emerged during whole-class discussions of the graphs and of the *Strategy Observation Tool*. Some students shared that they planned to "study hard" to prepare for a quiz, but they were not able to describe how the study would help them learn. For example, one student described plans for reading part of a textbook many times over, and others planned to practice a large number of problems. "Study hard" seemed to imply engagement in repetitive behaviors that were not necessarily focused on thinking and meaning. Because we thought the students would benefit from more explicit discussion of a variety of learning and study strategies, we pressed for detail in their descriptions of "what worked" and "what didn't work," as illustrated in this example (Pape et al., 2003):

Teacher 2: What did you do to build your confidence?

Student 4: I didn't understand it, so I went to my dad. He made me explain it to him.

Teacher 2: So, you rethought it with someone else. *How* did this help?

Student 4: I didn't understand how to unsquare it. I wasn't using all of my prior knowledge. But by explaining it to someone else, I remembered the parts that I didn't remember. (p. 191)

This excerpt of dialogue has three important implications for supporting the development of SRL in classrooms. First, the development of self-regulation was being supported through social interaction, which might be described as co-regulation within the developmental process. Second, the student's description of strategic behavior went beyond what had typically been reported on recording sheets and made this important strategic information available to all students. Third, without press for greater detail, the pivotal connection between explaining the concept to another person and the student's recall of prior knowledge would not have been made clear. The verbal expressions of strategies helped others in the class understand a greater range of possibilities for strategic behavior.

Analysis of our work with the seventh grade students indicated that a high level of student participation in classroom discourse and environmental scaffolding of strategic behaviors (e.g., modeling by teachers and students, whole-class discussions, feedback loops, and recording tools) were important to the development of self-regulated behaviors (Pape et al., 2003). Additionally, our reflection on use of the *Strategy Observation Tool* heightened our awareness of the need to provide varying levels of explicitness while supporting the development of SRL. All the students were exposed to a wide range of study strategies, but some students needed more individualized support for forming and enacting their plans.

Conclusion

This discussion of scaffolding the development of self-regulated learning began with assertions that contemporary conceptions of teaching and learning (e.g., NMSA, 2010; Kilpatrick et al., 2001; NCTM, 2000; NGAC-

CCSSO, 2010) require supporting more than content-specific knowledge. During classroom activity, teachers can engage students in the processes of self-regulated behavior (i.e., forethought, performance control, and self-reflection) and provide instructional support at appropriate stages of development (i.e., observational, imitative, self-controlled, and self-regulated) (Zimmerman, 2000) to foster the development of SRL. Students need guidance to practice strategic behaviors in real contexts, to monitor the effectiveness of using various strategies, and to reflect on the relationship between their strategic behavior and their performance outcomes.

The focus of instruction in all middle grades classes must expand beyond teaching subject-specific content knowledge and move toward supporting the development of strategic learning behaviors while teaching content. Attending to these developmental needs has potential for addressing both academic and personal development of young adolescent students (NMSA, 2010). We suggest scaffolding the development of SRL through reflective classroom discourse and through the use of a strategy observation tool as described above. Students themselves must be involved in monitoring and evaluating their learning behaviors to become self-regulated learners.

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